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85. Reeds, C.A. Earthquakes. 1934.

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87. Whitlock, H.P. The Netsuke of Japan. 1935.

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EARTHQUAKES

By CHESTER A. REEDS

THE LIBRARY BUILDING, STANFORD UNIVERSITY, CALIFORNIA, AS IT APPEARED
AFTER THE SAN FRANCISCO EARTHQUAKE OF APRIL 18, 1906

Reprinted from Natural History Magazine, December, 1934

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Earthquakes

An account of the sharp movements of the earth that often bring tragedy to the inhabitants of certain regions, together with an explanation of the instruments that record these movements

by
Chester A. Reeds
Curator of Geology and Invertebrate Palæontology, American Museum

THE needles on the seismograph in the American Museum may suddenly, without a moment's notice, begin to trace on moving sheets of paper a threefold series of wavy lines, which represent vibrations that have passed through the earth—somewhere there has been an earthquake and the seismograph is making a graphic record of it. If the shock is sufficiently strong, other seismographs in various parts of the world will inscribe a record of the same quake at approximately the same time. The vibrations from a strong distant quake may continue to arrive for an hour or more; those from a small near-by quake will be recorded in a much shorter time.

An earthquake is produced when the materials composing the earth are broken or displaced. The materials are hard, brittle, and elastic, and they will resist change until the forces acting upon them develop stresses greater than their strength, then they will yield suddenly and produce not only a fracture, but a shock. A sudden yielding of rocks to earth strains may give rise either to a new fracture or to movements along a previously existing fault. When a sudden movement does occur along a new or old fault, the frictional resistance offered by the opposing rock walls no doubt contributes its share to the development of vibrations. Whatever happens, the sudden shock releases energy, vibrations are set up and waves are transmitted through the earth in various directions to seismographs situated at different distances from the point of origin. The greater the dislocation, the greater the vibrations set up, and the greater the distance the waves will travel.

In the United States 62 major earthquakes and many smaller ones were recorded instrumentally for the year 1933. The average annual number of earthquakes locally sensible to human beings is about 4000. Of this number, about 70 are major quakes capable of instrumental registration over a hemisphere or the entire globe. There are some 200-odd seismological stations scattered over the surface of the earth. Many of these stations contain only a pair of seismographs, the larger stations contain three, four, or more makes of instruments, each with a different degree of sensitivity, and capable of registering, not only the horizontal, but also the vertical components of an earth shock. It has been recently estimated that the number of earthquakes, which probably occur annually, and which are susceptible of instrumental registration, approximate 8000. A limited number of modern seismographs have been in use for the past 35 years. During this period, it has been estimated that nearly 2500 major earthquakes have been recorded, and about 140,000 smaller ones, which may have been felt locally. The number which probably occurred, both large and small, and which may have been strong enough for registration by present-day instruments, may have amounted to 240,000. It may be noted thus that earthquakes are not of infrequent occurrence.

In recent years the citizens of the United States and of other countries have manifested a widespread interest in the occurrence and distribution of earthquakes and in the kinds of instruments which have been devised for recording them. With the gradual increase in the number of seismological stations in various parts of the

Wide World Photograph

A view of the wreckage of the city of Melfi, Italy, after the earthquake of July 23, 1930. Almost the entire Mediterranean is included in the geologically "young" zone that continues across Asia Minor and the Himalayas to the East Indies and beyond

Italy

Taormina, Sicily, looking toward the active volcano, Mt. Aetna, and with the ruins of an ancient Greek theater in the foreground. Taormina and Messina were severely shaken in 1908. The loss of life exceeded 100,000. The famous volcano of Sicily and the fact that earthquakes are not uncommonly felt in the island, demonstrate its geologic youth

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Wide World Photograph

An aërial view showing the ruins of Miyagi, Japan, as they were burning, following the destructive earthquake of March 3, 1933

Japan

Looking across Shoji Lake toward Fujiyama. This particular volcano is quiescent but others in Japan have played their part in the periodic earthquakes that are common in the Japanese archipelago

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civilized world, together with the improvements that have been made in the different types of self-recording instruments, there has been a marked increase in the number of earthquakes recorded.

The Composition of the Earth

The study which has been made during the past few decades of seismograph records has revealed that the earth has a crust composed of solid material, and that it has a thickness variously interpreted as being 40 to 60 miles in depth. The irregular configuration of the earth's outer surface is a matter of common knowledge. The highest point of land, represented by Mount Everest, has an elevation of 29,141 feet; the greatest depth of the sea, known as the Swire Deep, off the east coast of the Philippines, measures 35,433 feet. The maximum relief of the earth's surface is thus approximately 12¼ miles. The average height of the land, however, is but 2,300 feet above sea level, or nearly a half mile, while the oceans have an average depth of 11,500 feet, or a little more than two miles. The difference in relief between the average height of land and the average depth of the oceans is thus 2.6 miles. Only 28 per cent of the earth's surface is above sea level, the remaining 72 per cent being below. In other words, one part is land while nearly three parts are covered by water. This relative distribution of land and water is in keeping with the location of earthquakes, for maps showing the distribution of earthquake epicenters, for periods of one or more years, show that earthquakes are far more abundant at sea than on the land. It has been recognized by geologists and other scientists that the earth's surface has an irregular relief, because of the presence of materials of different densities near the earth's surface. Under the continents the densities, which average 2.67 times an equal volume of fresh water, are less than they are for the materials under the oceans, which are of the order of 3. The average density of the entire earth is considerably greater. It is 5.6 times as much as an equal volume of water. As a consequence, the materials of the inner parts of the earth must be denser and heavier than those of the outer crust.

We know, too, that the crust of the earth is rigid, although it is composed of materials of different consistencies, for, otherwise, the high areas would slump down and the materials composing them would move forward to fill the valleys, the ocean basins and their deeps, and produce a true spheroid, which would be covered with water to an average depth of about 7,500 feet.

The length of time during which the earth has had this irregular configuration is not definitely known. It has been long and may be of the order of the oldest known rocks, which are now regarded as exceeding a billion and a half years. High mountains such as the Alps, Andes, Caucasus, Himalayas, Rocky Mountains, and Sierra Nevadas have not always been high, for they are of comparatively recent origin geologically speaking; older mountains, such as the Appalachians of the United States, the Caledonian and Hercynians of Europe, have been greatly reduced in height by the action of the agents of erosion during many millions of years. The still older Laurentides of Canada, and the upturned strata of Manhattan Island and the adjacent mainland of New York have been reduced by these same agents of erosion to rolling uplands. Their present relief does not suggest mountains, but their geologic structure does. We may conclude from this evidence that while the high spots of the land and the low places of the sea have not always been where they are now, the relative distribution of the continental land masses and the oceanic basins has, with minor variations, remained more or less constant for vast geologic ages.

What Happens When the Earth Quakes

In regions where large earthquakes occur, it has been noted that either vertical or horizontal changes, or both, take place in the crust of the earth. The amount of change produced at any one time may be of

the order of a few inches or a small number of feet, and have a lineal extent of either a few miles, or as in the San Francisco earthquake of 1906, of several hundred miles. In the course of irregular periods, of long or short duration, earthquakes may recur in the same place or in closely adjacent areas; the combined result of a number of such recurring earthquakes is to produce a well marked change in the configuration of the earth's surface at that place. Earthquakes, which accompany either vertical or horizontal changes in the surface of the earth, are not only happening now, but they have occurred frequently during the past history of the earth. In fact, there is no portion of the earth's surface which is absolutely free of faults, those large fractures, which appear as mute evidence that earthquakes have occurred along them at one time or another during the past history of the earth.

It is also true that during past geologic ages parts of the earth's crust have been either down-warped, uplifted or broken, and in many cases, tilted. Evidence of this may be seen in many of our highest mountains where beds of limestone, sandstone, or shale, which contain fossil remains of shells that once lived in the sea, have been found at high elevations. Volcanoes also periodically bring up molten materials from great depths and pour them out at different elevations on the earth's surface. It would be of interest in this connection if we knew more precisely from what depth this white hot lava arises.

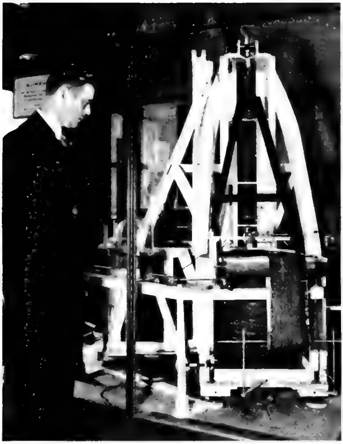
Where Earthquakes Originate

The depth at which earthquakes originate is a problem concerning which we would like to have more precise data. Many earthquakes produce evidence of shift of earth-blocks at the surface of the earth, others leave no trace of such movements. While some earthquakes undoubtedly occur near the surface, with movements extending downward, others appear to be deep-seated. A study of Japanese earthquakes by K. Wadati, 1928, shows that they may be either shallow or deep-seated. The shallow ones have an average depth of 25 miles, while the deep-seated ones may originate at depths of more than 186 miles. A few other investigators have made studies of this problem with varying results. The studies of B. Gutenberg in 1929 of sixteen different earthquakes show that the focus or point of origin of these quakes lies, with a few exceptions, at a depth of 28 miles or less. Some investigators of this problem say that, if the velocity of propagation of seismic waves through the uppermost layers of the earth's crust were more precisely known, there would be less uncertainty in determining the depth at which earthquakes originate.

Seismographs and Earth Vibrations

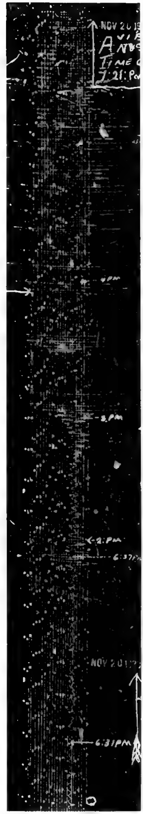
Seismographs are instruments designed to record the vibrations transmitted through the ground. During a great earthquake two things are apt to happen, namely: (1) There will be a lurch or displacement of the ground, either horizontal or vertical, or horizontal and vertical, the range of which may amount to 20 feet or more. The amount of displacement will not be recorded by the seismograph. It may be determined by resurveying the ground. (2) Vibrations will be set up in the ground.

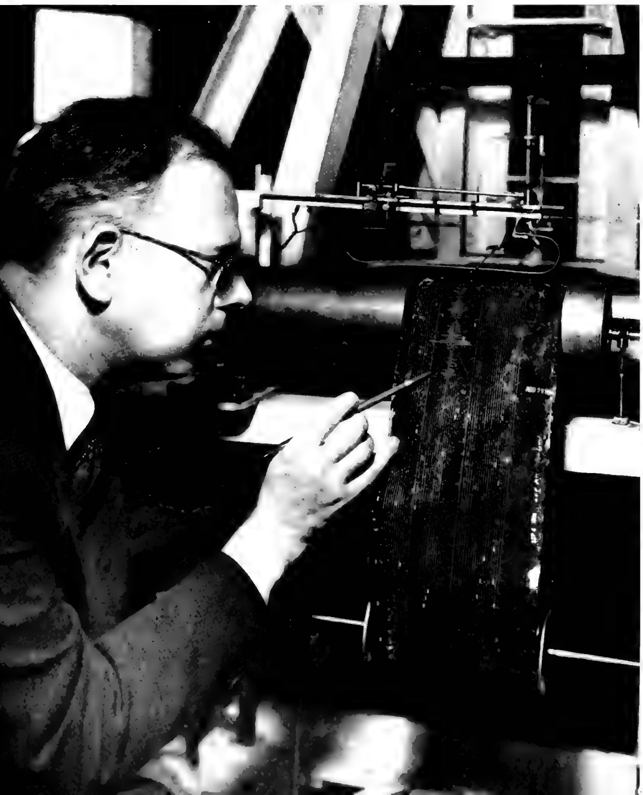
All earthquakes develop vibrations. The period of the vibrations may vary from a fraction of a second in near earthquakes to 20 or 30 seconds in distant earthquakes. No one seismograph will record all of these varied tremors. Due to limitations in construction and recording, different types of instruments are required for the registration of near and distant earthquakes. A third type of instrument, known as a tromometer, is needed for registering the minute tremors which precede and accompany volcanic eruptions. A fourth type of seismograph is required for those regions where great earthquakes occur, for there the motion is apt to be so strong and vigorous that any machine designed for the registration of other types of earthquakes would be damaged or thrown out of action.



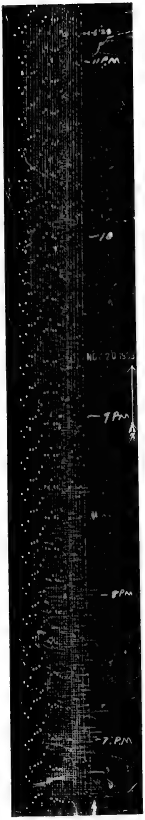
Seismograph

The photographs at the left and below show the seismograph at the American Museum of Natural History. The record which is being examined by the observer below records an earthquake of moderate intensity in the ocean bed on August 29, 1934. So accurate and sensitive are these instruments that though thousands of miles may separate them from the center of the earthquake shock, a study of the record will often determine the quake's location





Above: The seismographic record above and the one parallel to it on the opposite page are in reality two parts of one record, made on November 20, 1933, on the American Museum seismograph, recording a quake in Baffin Bay. Seismological stations have reported these shocks as being among the strongest ever recorded



Photograph by Charles C. Mook

Above: Trouble for a railroad. This view, taken immediately after the earthquake of July, 1925, at Three Forks, Montana, shows the havoc wrought on a railroad line by the displaced masses of rock loosened by the earthquake

Earthquake

A crack in the earth photographed after the earthquake of July, 1925, at Three Forks, Montana, not far from the spot pictured above. Such cracks in the earth are not uncommon after earthquake shocks, and sometimes can be traced for considerable distances

Photograph by Charles C. Mook

Each kind of seismograph consists of five essential parts, namely, (1) the "steady mass" which remains or should remain quiet during the time of an earthquake; (2) the framework which supports the "steady mass"; (3) the recording apparatus; (4) a damping device whose function is to keep the "steady mass" quiet; and (5) a pier constructed in such a manner that it stands free of buildings and is firmly connected to the ground.

The Mainka Seismograph

In the American Museum installation there are two horizontal pendulums, known as the Mainka seismograph and built precisely alike and set at right angles to each other. One is placed in a N-S direction, the other in an E-W plane. The N-S instrument registers the E-W component, the E-W instrument the N-S component of an earthquake movement. The "steady masses" in these two seismographs have been painted black. Each consists of a series of 16 alternating iron and lead discs which have been stacked in such a way that they make a cylinder 15½ inches in diameter and 22 inches high. The weight of each "steady mass" is 450 kilograms or nearly 1000 pounds. Each "steady mass" is supended from a sturdy angle-iron frame, painted white, which rests upon a concrete pier. The top of the pier, which has dimensions $3' 8'' \times 5' 8''$ and supports both instruments, is level with the first floor of the Museum building. It is not connected with the building, however, for an air space separates them. The pier, which extends downward 24 feet, has its lower half firmly imbedded in Manhattan schist. The upper half of the pier passes through the basement of the building and there it is surrounded by a wall of hollow tile. This tile wall not only protects the pier, but it keeps the air surrounding the pier of a uniform temperature. Air conditioning of seismograph piers is an important matter, for, if not attended to, the seismograph records are apt to show unnatural earth tilts brought about by unequal changes in temperature in the piers.

The mode of suspension of the "steady masses" varies in different types of instruments. The "steady mass" may be supported in such a manner that it represents either a common pendulum, an inverted pendulum, or a horizontal pendulum. In these various types of suspension, the equilibrium of the "steady mass" is respectively stable, unstable, and neutral. Of these three types of pendulum the horizontal one offers the least amount of difficulty in providing a "steady mass," which is essential in an accurate seismograph. The horizontal pendulum, therefore, is the one generally used in the construction of seismographs. A door or gate swung on two hinges is a common example of this type of pendulum.

In order that the horizontal pendulum may have a small amount of stability and may return to its initial position after displacement, the axis of support is tilted slightly toward the center of gravity of the "steady mass." Swinging doors and gates also readily come to rest when they are not hung perfectly true.

The Arrangement of the "Steady Mass"

In a simply constructed horizontal pendulum the "steady mass" is usually firmly attached to one end of a boom; the other end of the boom, which is free, ends in a steel point which is pivoted in an agate cup near the base of the mast or supporting frame. The weight of the "steady mass" is supported in mid air by a wire stay, which is attached at one end to the weight and at the other to the top of the mast. This mode of attachment not only keeps the "steady mass" free of its supporting frame, but it permits adjustment of the angle which the boom makes to a horizontal plane passing through its pivoted end. This angle affects the period of the instrument, in other words, the number of vibrations which the "steady mass" will make in a second, when touched lightly with the finger. For near earthquakes a period of four to six seconds is suitable; for distant earthquakes one of thirty seconds or even greater is desirable.

In the American Museum installation of the Mainka seismograph the "steady mass" is kept free of the supporting frame by a Y-shaped yoke, the two distal ends of which are attached to the sides of the mass, while the free proximal end is fastened to the frame in such a way that a knife-blade spring is kept under tension. The lower end of the supporting stay consists of a bridle fastened to the two ends of a pipe which passes through the center of gravity of the "steady mass"; the upper end of this support terminates in a wire which is attached to the top of the supporting frame. The suspension is so delicately adjusted that, if the "steady mass" is slightly touched with the finger, it will swing back and forth in a horizontal plane and the vibrations will be registered by the recording needle on smoked paper. From such a registration the natural period of the instrument can be obtained. In this connection it may be stated that a seismograph is most sensitive to those waves which correspond to its own natural period of vibration. The period of the machine is noted at the beginning of every record. New sheets of paper are placed on the instruments, usually at the end of every forty-eight hours.

The "Damper"

The movement of the "steady mass" when touched is just the contrary of what happens when an earthquake occurs; then the earth, the concrete pier, and the white supporting frame vibrate as a unit while the "steady mass" remains quiet, at least for a time, when it may begin, if not damped, to pick up the earth's vibrations transmitted through the supporting boom and stay.

The damper which is placed upon the side of each supporting frame consists of a rectangular metal box, a pair of round air holes near the top with adjustable covers, a sheet of metal within the box which acts as a diaphragm, and a set of rods which connect the diaphragm with the center of the "steady mass." This is an air damper; oil and magnetic dampers are also used on some types of seismographs. The damper offers resistance to any sudden movement which may take place, especially the tendency of the pendulum to swing in its own natural period when an earthquake occurs.

How the Recording Apparatus Operates

The recording apparatus in each instrument consists of a connected series of multiplying levers. One end is attached to the center of gravity of the "steady mass"; the other end is a freely moving well-balanced recording needle which lightly touches a moving sheet of smoked paper. These levers magnify the earth tremors 100 times. In order that the earth movements which pass through the pier and supporting frame may be registered with reference to the "steady mass" which remains quiet, the recording levers are also attached to the center of the "steady mass," the diaphragm of the damper, and to the supporting frame. In addition to the multiplying levers, the recording apparatus in the Mainka seismograph consists of a pair of revolving drums on which sheets of smoked paper 15×90 centimeters in size, and joined at the ends, rotate past the point of the recording needles. The movement of the drums and smoked paper, which is at the rate of 15 mm. per minute, is controlled by a weight and governor. Minute and hour dots are marked on the sheets of smoked paper by a pointer, which is controlled by a master wall clock having electrical contacts.

Normal registration of a Mainka seismograph appears to consist of a series of parallel lines traced by the needle on smoked paper. Actually the needle traces a continuous line of closely appressed spirals, as when a garden hose is coiled up, for the paper moves over slightly as it climbs the higher side of the gently inclined drums.

During an earthquake the needle swings back and fourth across the paper and thus inscribes the vibrations of the earth which usually arrive in three phases known as the First Preliminary tremors, *P;* the Second Preliminary tremors, *S;* and the Main Waves, *L.* In distant earthquakes one or

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The photograph at the left, taken at Compton, California, shows how the wall of a building crumbled away as the result of a quake. Below is a view of San Francisco which in 1906 was fearfully damaged by an earthquake followed by fire

California

New Zealand

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The photograph at the right was taken at Napier, New Zealand, Feb 3, 1931, while an earthquake was still in action in the vicinity. The view below is at Aukland, which was shaken by the great quake of 1931. New Zealand is periodically subject to earthquake shocks

two reflections of these waves at the earth's surface may occur, at one-third and two-thirds the distance, and be recorded as superimposed phases. The first case may be designated as PR1, SR1, and the latter as PR2 and SR2. The seismograph record of such tremors indicates not only the paths by which the various kinds of waves reached the instrument, but also the properties of the materials through which the waves passed. The earth thus not only writes its own epitaph, but this inscription is full of meaning and is worthy of our careful inspection. For distant earthquakes, the beginnings as well as the continuation of the different phases of the record are indicated on the seismogram by sudden or gradual increases of amplitude, by sudden change of period, or both, and by the order of succession in which they occur. For instance, it has been determined that the P-waves, the first to arrive, are longitudinal or compressional waves with vibrations in the direction of progress. They are fast and of small amplitude, usually less than a millimeter. Their velocity near the surface is 7 to 8 kilometers per second and their period varies from 5 to 7 seconds. They usually follow a direct path from the point of origin to the recording seismograph, but a curved one, since in passing through, they dip toward the center of the earth where the rocks are denser and their rate of propagation is faster.

Waves and Vibrations

The S-waves are transverse or distortional with vibrations at right angles to the direction of progress. They are slower than the P-waves, and have a velocity near the surface of about 4.5 kilometers per second. Their period is 11 to 13 seconds. They follow approximately the same path as the P-waves.

The main or long waves, L, which pass around the surface are complex longitudinal waves. Their velocity is 3 to 4 kilometers per second, depending on conditions. According to N. H. Heck, chief seismologist of the U. S. Coast and Geodetic Survey, their velocity under the Pacific ocean is about 20 per cent greater than under the continents. Their periods vary greatly and may be as large as 40 or 60 seconds.

The P and S waves of sharp, well defined single shocks can be definitely differentiated on a seismograph record for those earthquakes which originate at places more than 700 miles and less than 7000 miles distant from the recording instrument. Furthermore, with an accurate timing apparatus the times of arrival of these waves can usually be definitely determined on the record, the difference noted, and the distance from the receiving station to the point of origin (epicenter) calculated, or read off from an empirical table or its graph, with an error not greater than 25 to 50 miles. By using the determined distance as a radius, and the location of the station as a center, a circle may be inscribed on a globe, or scaled map, which will pass through the epicenter. Its location on the circle may be determined by applying the same method to distances obtained from two other widely separated stations, using one or the other of those stations as the center of the second and third circles. The point of intersection of the three circles, or the center of the triangle formed by them, will be the location of the epicenter. The use of the duration of the first preliminary tremor for determining the position of the epicenter of a distant earthquake is known as the Zeissig method. It is the one used by most observers. Other methods are sometimes used but they require special apparatus.

Whatever method is used it may be noted that since 1899 there has been an ever-increasing accuracy in locating earthquakes, especially those 700 to 7000 miles distant from recording stations. The location of the main seismic areas is now well known—one belt extends around the margins of the Pacific Ocean, another forms a great circle about the earth through the Mediterranean-Caribbean regions. Other areas of frequency are less well defined, for isolated occurrences are common in many parts of the world, except

H. Armstrong Roberts, photo

Extending in a vast horseshoe from Cape Horn up the coast of the Americas across to Asia and down to the East Indies is a great band which includes mountains and islands of geologically recent formation. Most of the West Indies also are included in this region throughout which earthquakes are occasionally experienced. The view on the right was taken on the island of Puerto Rico, and the photograph below shows the Chilean Andes rising abruptly from the sea

Publishers Photo Service

Athens

A view of the city from the top of the Stadium. Both Greece and Palestine occasionally feel the effects of earthquakes, for old though these regions are in the history of civilization, they are comparatively young as the geologist measures the age of the earth.

Right: A view of the Temple of Jupiter with some of its fallen columns. Many of the Greek ruins have been brought to their present condition by earthquakes

Publishers Photo Service

in the polar regions, where few earthquakes have been registered during the past thirty-five years.

For near-earthquakes, that is, those that occur within 10°, or 700 miles, of the epicenter, there is no separation, on most seismograph records, of the primary waves, P, and of the secondary waves, S, and it has been suggested that for this distance each wave possesses both types of characters. In other words, the characteristic features of these waves, condensational on the one hand and distortional on the other, are not differentiated on seismograph records made by instruments designed and set for those quakes originating 700 to 7000 miles away and known as distant quakes. Specially constructed instruments are required to separate P and S waves of near-earthquakes.

Those far distant earthquakes, which originate 7000 to 10,000 miles or farther from a recording station, do not register the P waves, as the first recorded impulses, since these waves are refracted at a depth of 2900 kilometers (1802 miles) into the inner core of the earth and produce by their refractions what is known as the "blind zone." Such refracted waves, when recorded, are designated at P′ waves. The velocity of these waves just ouside the central core is 13 kilometers (8 miles) per second; inside it is 8.5 km. (5.3 miles) per second.

So far as we know the S-waves originating 7000 to 10,000 miles distant do not emerge from the inner core and we may assume, since they are not transmitted through substances in a liquid or gaseous state, that the inner core, with radius 3470 km. (2157 miles) or .55 of the radius of the earth, is in a liquid or gaseous condition and composed of a molten mixture of the heavy metals iron and nickel.

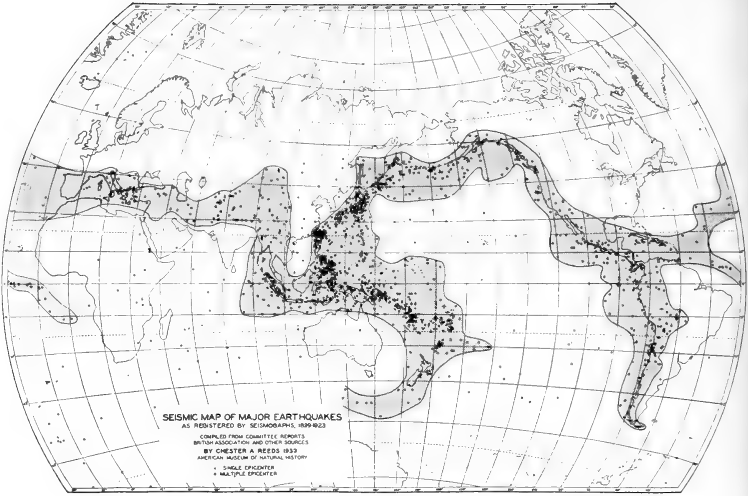
The study of distant earthquake records has indicated that the surface of the inner core is a well marked surface of discontinuity, and that it refracts or reflects the waves which meet it. Some four other less pronounced discontinuities separate the zones of the earth which appear above it.

The one appearing at a depth of about 60 kilometers (37 miles) is well marked in many seismograph records. It is the lower margin of the crust of the earth.

These planes of discontinuity change the path and energy of earthquake waves.

Problems to be Solved

The foregoing discussion gives a brief resumé of the general status of our knowledge concerning the earth's interior, the propagation of earthquake waves, and the significance of seismograph records. While various seismological investigations have been carried on during the past thirty-five years, which have thrown a flood of light upon hitherto unsolved problems and hidden features of the earth, we would like to know more about the earth's interior, the elastic properties of the earth, the conditions which produce earthquakes, and the composition and structure of the layers composing the crust. Geological observations on surface indications during the past 150 years lead us to believe that the crust is composed of numerous layers of rock which are variable in number, extent, origin, structure, and composition. The recent development of seismic prospecting for oil and other minerals and the effect of the propagation of earthquake waves on buildings and other structures emphasize the importance of these researches. Daily observation and studies are being conducted by various organizations. In the United States they are being carried on by the National Government through the Coast and Geodetic Survey with the coöperation of the Weather Bureau, the Geological Survey, the Bureau of Standards, and the National Research Council. Other organizations are also coöperating, such as the Carnegie Institution of Washington, the Jesuit Seismological Association, and the various universities, colleges, and museums in different parts of the country. The ultimate aim of this study is a better understanding of the elastic conditions of the earth.



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A SEISMIC MAP OF THE WORLD

By Chester A. Reeds

This map shows the epicenters of 1783 major earthquakes. These large earthquakes were recorded at various seismological stations during the twenty-five-year period 1899–1923. The data for the map were compiled from the reports of the Seismological Committee of the British Association, the Canadian Observatory, the Seismological Society of America and other organizations.

The solid black dots show the location of single major disturbances. The circles with one or more radiating rays indicate places where large earthquakes have been repeated at different times during the twenty-five-year period. Each ray represents a recurrence. Some circles have as many as sixteen rays. Major earthquakes are usually produced by pronounced movements along fault planes. They generate waves of sufficient intensity to pass through the earth and be recorded at seismological stations situated at points more than half way around the earth from the place of origin. Those numerous minor quakes which are recorded by nearby stations and which may have exceeded 100,000 in number during the twenty-five-year period, are not shown on the map. If they had been plotted they would show a more widespread distribution. Most of them, however, would be confined to the shaded zone which represents those belts of the earth where the highest and youngest mountains and deepest troughs of the oceans occur.

The map shows that most earthquakes originate in rocks beneath the oceans and that they are confined for the most part to two great belts, one running from west to east through the Mediterranean and Caribbean Seas and the other adhering to the margins of the Pacific Ocean. The ancient shields of the continental masses, which include the great ice wastes of the polar regions, are underlaid by old rocks which are, for the most part, free of earthquakes.

Prior to the development of modern seismology by John Milne and his associates in the late Nineties, our knowledge of the occurrence of earthquakes was confined to the destruction wrought by them on land. From instrumental records, we now know that most earthquakes originate beneath the oceans and in those parts of the land where geomorphic changes are taking place in the crust of the earth.

INTRODUCTION TO HUMAN ANATOMY

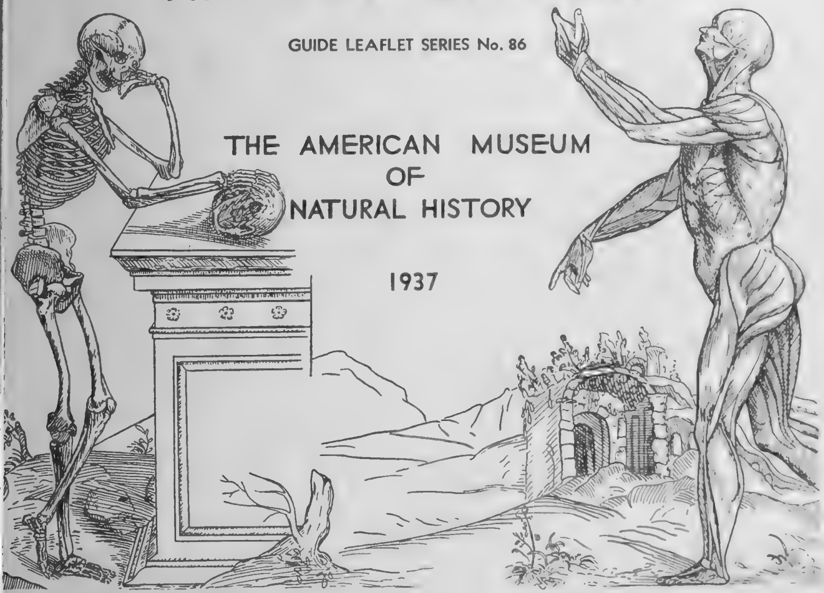
By

WILLIAM K. GREGORY

and

MARCELLE ROIGNEAU

GUIDE TO SECTION I OF THE HALL OF NATURAL HISTORY OF MAN



GUIDE LEAFLET SERIES No. 86

THE AMERICAN MUSEUM OF NATURAL HISTORY

1937

Issued under the direction of the Committee on Popular Publications.

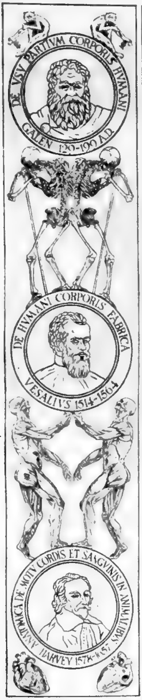
Roy W. Miner, *Chairman*

GUIDE TO SECTION I OF THE HALL

OF

THE NATURAL HISTORY OF MAN

The EVOLUTION OF ANATOMY



THE SCIENCE OF ANATOMY SPRINGS FROM TWO MAIN SOURCES: FIRST, MAN'S SEARCH FOR THE CAUSES OF HIS BODILY PAIN; SECONDLY, FROM HIS CURIOSITY ABOUT HIMSELF. THE FIRST MOTIVE GIVES RISE TO SURGERY, OR APPLIED ANATOMY, AND MEDICINE; THE SECOND TO COMPARATIVE ANATOMY, OR, MORPHOLOGY. THIS DEALS WITH THE STAGES THROUGH WHICH A GIVEN ORGAN HAS PASSED DURING ITS EVOLUTION.

AMONG THE ANCIENTS ANATOMY WAS LARGELY MIXED UP WITH ASTROLOGY AND OTHER FORMS OF FORTUNE TELLING AND MADE COMPARATIVELY LITTLE PROGRESS UNTIL ARISTOTLE (BORN 384 B.C.) LAID THE FOUNDATIONS OF COMPARATIVE ANATOMY, AND GALEN (129-199 A.D.) FAIRLY OPENED UP THE SCIENCE OF ANATOMY, PARTLY ON THE BASIS OF HIS DISSECTIONS OF THE BARBARY APE.

AFTER A LONG ECLIPSE OF ANATOMY DURING THE DARK AGES (200 TO 1050 A.D.) THE SCIENCE WAS REVIVED AT BOLOGNA, PADUA AND OTHER UNIVERSITIES OF THE MIDDLE AGES.

THE GREAT ARTIST LEONARDO DA VINCI (1452-1519) LEFT BEHIND HIM A SERIES OF WONDERFUL DRAWINGS OF HUMAN ANATOMY. HE WAS FOLLOWED BY VESALIUS (1514-1564) THE FOUNDER OF MODERN ANATOMY.

AMONG THE GREATEST ADVANCES IN MODERN ANATOMICAL KNOWLEDGE MAY BE MENTIONED THE FOLLOWING:

(1) THE DISCOVERY OF THE CIRCULATION OF THE BLOOD BY WILLIAM HARVEY (1616).

(2) THE INVENTION AND DEVELOPMENT OF THE MICROSCOPE AND OF MICROSCOPIC ANATOMY, OR HISTOLOGY BY LEEUWENHOEK (1632-1723) AND HIS SUCCESSORS. THIS HAS MADE POSSIBLE THE MODERN SCIENCE OF EMBRYOLOGY, GENETICS, EXPERIMENTAL BIOLOGY, ENDOCRINOLOGY, ETC.

(3) THE FOUNDING OF MODERN COMPARATIVE ANATOMY AND PALAEONTOLOGY BY CUVIER.

(4) THE DISCOVERY OF THE "ECHELLE DES ETRES" OR SCALE OF LIFE AMONG RECENT FORMS, BY BUFFON, LAMARCK, DARWIN AND THEIR SUCCESSORS. THIS GAVE NEW LIFE AND MEANING TO COMPARATIVE AND HUMAN ANATOMY.

(5) THE DISPROOF OF THE DOCTRINE OF THE FIXITY OF SPECIES AND THE ACCUMULATION OF PROOF THAT DURING THE COURSE OF AGES THE HIGHER ANIMALS HAVE BEEN DERIVED FROM LOWER TYPES BY DESCENT WITH MODIFICATION, BY CHARLES DARWIN (1859) AND HIS SUCCESSORS.

THUS THE HISTORY OF THE STRUCTURE OF MAN BECOMES PART OF THE HISTORY OF THE VERTEBRATES IN GEOLOGIC TIME.

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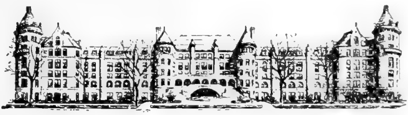

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CONTENTS

PREFACE

The exhibits on the south side of the hall are designed to give an introduction to human anatomy, to show by simple examples how the machinery of the body works, and especially to trace the origin and rise of the principal systems of organs.

The synopsis of the exhibits is as follows:

How man, like other organisms, derives his life-energy from the sun and how he spends it (Case I).

The ground-plan of each of the main organ systems of man is present in such a primitive form as a shark (Case IIA).

The evolution of the motor system, from its simple beginnings in the fish to the upright-walking motor system of man (Cases IIB, III, IV, and VA).

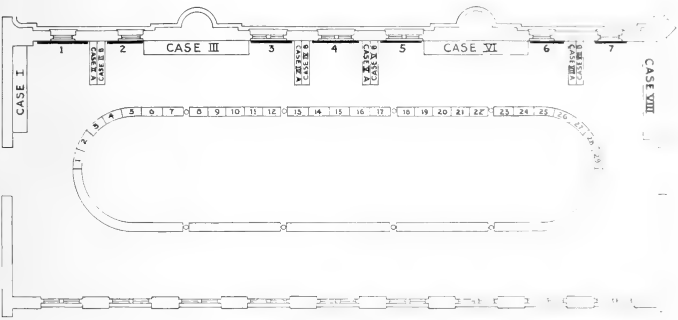
Embryology, or development of the body before birth (Case VB).

The history and origin of the human face, the skull, jaws and teeth (Cases VI and VIIA).

Chief characters of the nervous system, including the organs of sensation and response (Cases VIIB and VIII).

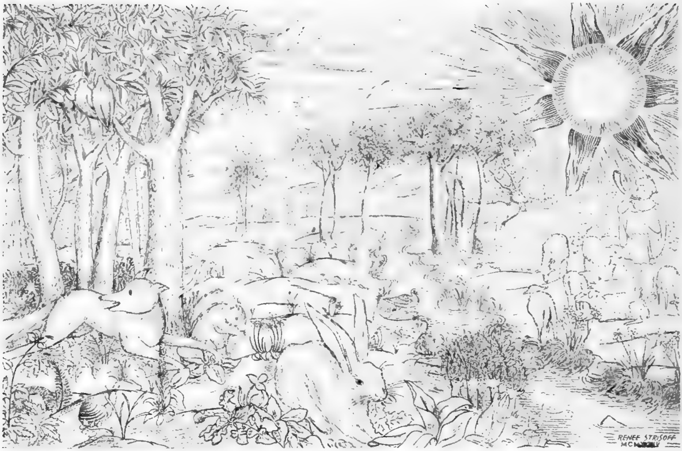
The wall charts show man's place among the vertebrates.

This Hall, although not completed, was opened to the Public in August 1932, in connection with the Third International Congress of Eugenics.



Floor Plan of the Hall

The numbers are those which may be found marked on the cases.



THE SUN

Chief Source of Human Energy

Man, like other animals, draws his supply of energy from the sun.

The sun is the source of the energy stored up in plants. It is the leading factor in the forces which have made the earth fit for human habitation. Without the sun man could never have appeared; without it he could not survive a moment.

Man, however, cannot absorb the sun's energy directly, as the plants do; he must take it in his food, thus appropriating it from other animals and from plants.

The green coloring matter (chlorophyll) of plants has the power of absorbing some of the red, blue and violet rays of the sun, using them to transform raw materials into food for the plant's growth.

These raw materials are carbon dioxide, which the plant takes from the atmosphere, water, dissolved nitrates and other salts, which it draws up from the soil.

When the chlorophyll, with the aid of the sun's rays, breaks up these substances, the carbon is pulled out of the carbon dioxide and the hydrogen out of the water.

After a complex series of chemical reactions the finished products appear as sugar, starch and other carbohydrates, fats and proteins, which are the food-stuffs of both plants and animals.

Every animal is endowed with the power of locomotion so that he may either pursue the prize or flee from those who would wrest it from him. And when he has overtaken it he devours it, that it may sustain his life. But that he may know what to eat and what not to eat, when to run and when to fight, Nature has bestowed upon him a keen eye and an understanding brain.

Thus the energy of the sunlight, stored up in the substance of plants and animals, becomes a hidden treasure of great worth, to obtain which all animal life labors and struggles unceasingly.

THE LIVING CHEMICAL ENGINE

[Case I]

The human body is often compared to an automobile: the consumption of food recalls the combustion of the fuel; the contraction of the muscles is like the action of a piston on a shaft; also unless the products of combustion are thoroughly eliminated the machine becomes choked with its own waste. Such a comparison, however useful is quite inadequate, for the body, considered as a living organism dominated by its own control system, is infinitely more complex than a lifeless machine.

The body has also been likened to a whirlpool, which is constantly seizing upon new inert matter from the outside, whirling it around and then ejecting it. The body is also like the flame of a candle, which lives only as long as its food supply lasts and its wick holds out. But it is rather to be considered as a conscious flame that seeks out suitable fuel and makes its own wick.

By means of its cells the body as a whole has the properties of IRRITABILITY, MOTION, METABOLISM[1], GROWTH and REPRODUCTION, common to living organisms.

The body is first of all a commonwealth of active living cells that dwell in the midst of non-living substances which they have secreted; or they float in a watery fluid or lymph.

A cell is normally a mass of protoplasm containing a nucleus, or center of cell activities. Protoplasm itself in its most typical form is a colloidal or jelly-like substance permeated with globules. It contains much water, a little salt in solution and chiefly proteins, or nitrogenous compounds, in suspension and fat droplets in emulsion. The cells are separated by membranes or walls; these membranes permit varying concentrations of certain chemical compounds in the cell; they are also like filters in straining out insoluble substances; by OSMOSIS the membranes also permit the passage of fluids of different degrees of acidity in opposite directions. The motive force of all these movements, as well as the contractility of muscle cells, is to be found in the various electric charges of the different kinds of aggregates of molecules, especially of the very complex protein molecules.

All the activities of the body are dependent upon these and similar conditions.

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[1] The process of breaking down and building up organic substances.

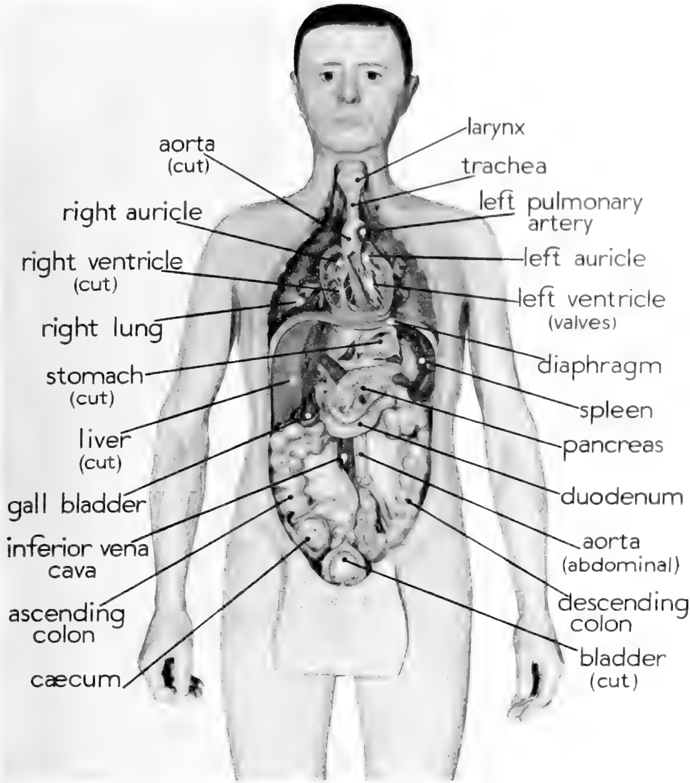


Fig. 1. The hidden parts of the human engine

Model showing the interior of the chest and abdomen, after the removal of the stomach and other organs.

Based chiefly on the plates in Spalteholz' Hand Atlas of Human Anatomy. Model by Christopher Marguglio.

All cells in the body have been derived by subdivision from the single zygote or combined male and female sex-cell; nevertheless they have become differentiated by regions into manifold tissues, with diverse chemical and physical properties.

What the Body is Made of

WATER	**FATS**
CARBOHYDRATES	**INORGANIC SALTS**
PROTEINS	**VITAMINS**

These chemicals make up the food we eat and are therefore what we ourselves are made of.

Water heads the list, forming about 65 per cent of the body weight. Water circulates in all our arteries, veins and lymph vessels, carrying other substances in solution and in combination; it dissolves the food and is an indispensable element in digestion; it washes out injurious products through the kidneys; it forms a greater or lesser part of all the bodily tissues. Water comes into the body in all food and drink; it escapes as vapor from the lungs and skin and goes out as liquid in the urine and feces.

Carbohydrates. The energy of the sun's rays, when passed through the green coloring matter of plants, builds up water and carbon dioxide (CO_2) into glucose and other forms of sugar, and into starches. These carbohydrates taken in as food must all be reduced, through the process of digestion, to glucose, a simple sugar, before being carried by the blood stream to the liver and the muscles. Most of the energy of the carbohydrates is used as fuel for the muscle engines.

Proteins. Proteins are very complex compounds of carbon, hydrogen, oxygen, and nitrogen; most of them also contain sulphur and some contain phosphorus. Albumen, or white of eggs, is a protein in a weak salt solution.

Plants draw up nitrates from the soil and combine their nitrogen with carbon dioxide and water to form amino-acids, which are in turn built up into different plant proteins.

The animals, including man, are not able to form amino-acids from such simple materials; herbivorous animals must obtain amino-acids in the form of "vegetable proteins"; carnivorous animals rely chiefly on "animal proteins"; omnivorous animals, including man, can use both.

In the course of digestion these proteins taken in as food are decom-

posed by a series of hydrolyses[1], into their respective amino-acids, which are then absorbed into the blood stream and carried first to the liver; then they are distributed from the liver to the various tissues of the body, where they are built up into the characteristic proteins of the particular tissues.

The wide geographic distribution of mankind is partly dependent upon man's ability to eat many kinds of food and to utilize them all either for work or for the storage of energy.

Fats. These are compounds of carbon, hydrogen and oxygen. By the action of the pancreatic juice and the bile the fats taken in as food are split into glycerol $C_3H_5\ (OH)_3$ and fatty acids; these are then absorbed by the intestinal epithelium where they are recombined into neutral fats. Then instead of passing directly into the blood stream, they are taken up by the lymph vessels as chyle and are poured with the lymph into the blood from the thoracic lymph duct.

However, most of the fat stored in the body is the product of the synthesis of any excess of carbohydrates that may occur.

Inorganic or Mineral Salts. (Not sources of energy.)

Calcium. When bone is burned, lime (calcium oxide) is left in the ash along with other "earthy salts." Calcium phosphate $(Ca_3\ (PO_4)_2)$ forms most of the hard parts of the skeleton. Also to a less extent calcium carbonate $(CaCO_3)$. Weak solutions of calcium chloride $(CaCl_2)$, sodium chloride $(NaCl_1)$ and potassium chloride (KCl) are essential for alternate contraction and relaxation, or tonus, of the heart muscles. That is, the rhythmic beating of the heart depends partly on the antagonistic action between these salts. Such antagonistic reactions between salts are probably requisite for the maintenance of the proper degree of permeability in cells. For example, calcium has a balancing or compensating effect on metabolism. Milk is especially rich in calcium; but many other foods contain small amounts of it.

Sodium chloride, or common salt, occurs in the blood plasma and other fluids of the body. **Potassium,** on the other hand, occurs most abundantly in the soft solid tissues, the corpuscles of the blood, the protoplasm of the muscles, also in certain secretions, e.g., milk. Most vegetables are rich in potassium.

A conspicuous function of the salts in the tissues is the maintenance of the normal osmotic pressure. The plasma, or clear fluid of the blood, consists of about 90 per cent water, 9 per cent proteins and .09 per cent

[1]*Hydrolysis:* from Greek *hydros*, water and *lysein*, to loose.

salts. Sodium chloride is excreted through the kidneys. Potash (potassium) salts tend to cause the loss of sodium and chlorine. The craving for common salt (sodium chloride), when one is eating vegetable food, especially potatoes, tends to correct undue loss of chlorine and sodium.

Phosphorus enters into the nucleo-proteins of the cell nuclei, which are very active in metabolism and growth. Phosphorus is an important element of the nerve cells, and particularly of the skeleton. Many foods contain phosphorous compounds, especially milk and egg yolks.

Chlorine is found both in the chlorides of the bloodstream and in the hydrochloric acid of the stomach. This acid seems to be formed through the decomposing action of a certain protein on sodium chloride in the presence of carbon dioxide.

Iron is present in excessively small quantities in red blood corpuscles, where in combination with Carbon, Hydrogen, Nitrogen and Oxygen it forms hæmatin, which in turn is united with a protein, "globin," to form hæmoglobin. This extremely complex substance contains several thousands of atoms of carbon, hydrogen, nitrogen and oxygen to every one of iron. Hæmoglobin carries oxygen from the lungs to the tissues of the body. Iron is present in certain foods, especially in egg-yolk, barley, spinach and liver.

Iodine. This element is very important in the secretions of the thyroid gland.

Vitamins ("accessory food-stuffs") are organic food materials, not in themselves significant sources of energy but essential, in some way not yet definitely known, to normal metabolism; e.g., children whose food lacks vitamin D develop rickets, while want of vitamin C causes scurvy.

Digestion and Absorption

In chemistry a substance is said to be "digested" when it is exposed to the action of hot liquid. Digestion is also defined as a process of HYDROLYSIS, the breaking-up or decomposition of a complex substance, some of whose parts unite with the hydrogen and oxygen of water. Water is therefore an absolute necessity for digestion.

The diagrams (Fig. 2A, B) indicate how the several divisions of the digestive tract pour certain reagents into the food-containing solution.

The complex carbohydrates, fats and proteins of the food are thus broken down into simpler substances, such as glucose, fatty acids, amino-acids, etc. These soak through the mucous membrane of the intestine and are reconverted into such forms of carbohydrates, fats and

proteins as can be assimilated by the body; after being absorbed by the walls of the capillary blood-vessels of the digestive tract, (except the fats which are first taken up by the lymph vessels) they are carried eventually to the heart, whence they are pumped to all parts of the body.

Blood Corpuscles

(The Currency of the Body)

The energy contained in the food-stuffs is carried to the billions of the body's cells by the circulating medium, including the blood and lymph streams. The blood stream also carries the oxygen from the lungs to all the tissues of the body. The principal units of the circulation are: the red blood corpuscles, the white blood corpuscles and the blood-platelets. All these float in the watery plasma of the blood.

The **red blood corpuscles** (erythrocytes) are extremely minute, there being about five million in one fifteen-thousandth of a cubic inch (=1 cubic millimeter); also they are so numerous that a man weighing 154 pounds has in his blood about 30,000,000,000,000 of them, which if spread out side by side would cover about 4,400 square yards.

The red coloring matter, or hæmoglobin, consists of an iron-containing pigment combined with a protein. Hæmoglobin has the power of carrying oxygen from the lungs, of giving it up to the tissues and of receiving from them the waste gas, or carbon dioxide, which is again carried to the lungs to be given off into the outer air. The red blood corpuscles originate in the red marrow of certain limb bones.

In man, as in other mammals, the red corpuscles at first have a nucleus but later expel it.

The **white blood corpuscles** (leucocytes) are amœba-like cells which can pass through the walls of the capillary blood vessels to form the pus or matter of inflamed parts. There are several kinds of leucocytes. One kind, called microphages, derived from cells in the red bone-marrow, engulfs and devours foreign bacteria in the blood stream and thus protects the body against certain diseases. Others, called lymphocytes, are necessary in elaborating some of the food-products so that they can be taken up by the tissues. These originate in the lymph glands.

The **blood-platelets** are exceedingly minute. They have the important function of assisting in the clotting of the blood.

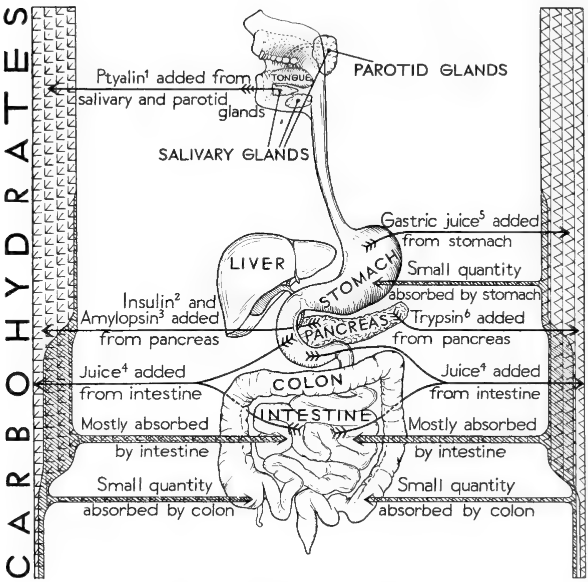


Fig. 2A. Digestion and absorption of foods.

1. Ptyalin (salivary diastase) turns starch into soluble sugar (maltose).
2. "Islands of Langerhans" (in pancreas) give insulin, a hormone which enables tissues to take up sugar actively.
3. Amylopsin (pancreatic diastase) splits starches.
4. Intestinal juice continues digestion of carbohydrates and proteins.
5. Gastric juice = free hydrochloric acid + pepsin (from stomach) converts proteins to intermediate products.
6. Trypsin (pancreatic juice) splits proteins.

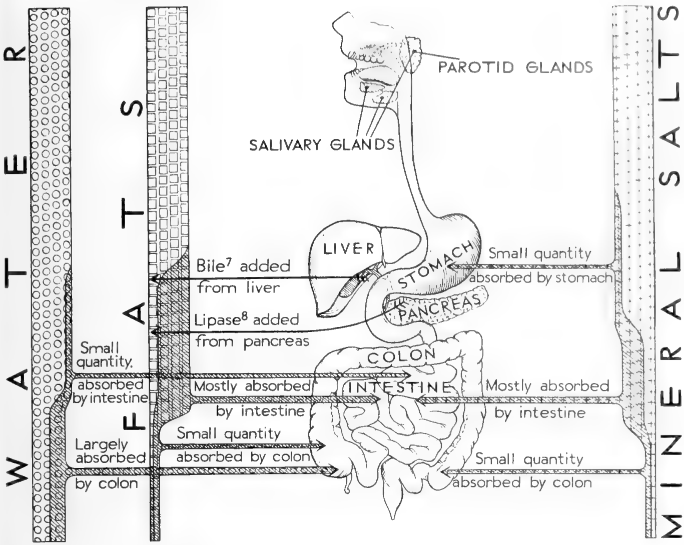


Fig. 2B. Digestion and absorption of foods (continued)

7. Bile, or gall (from gall bladder in liver) greatly accelerates action of lipase in splitting fats.
8. Lipase (pancreatic juice) splits fats, converting them to fatty acid and glycerol.

Diagrams based on the illustrations and data published in *Der Mensch* by Martin Vogel.

The Solar Energy is Utilized by the Muscles

The chlorophyll of the plant, as already shown, utilizes the energy of the sunlight to build up sugar and starch out of water and carbon dioxide. These carbohydrates taken in as food are turned into glucose by the digestive juices of the intestine. The blood stream carries the glucose to the liver, where it is converted into glycogen or animal starch (which is the anhydride of glucose).

The liver then stores up the glycogen for future use.

Indirectly, the combustion of glycogen furnishes the heat and energy necessary for the life of the higher animals, but the direct energy of the muscles is due to the breaking down of a creatine-phosphoric acid compound.

Creatine is an amino-acid which is present in muscle tissue.

Insulin, a hormone manufactured by the Islands of Langerhans in the pancreas, is also essential for the proper combustion of carbohydrates in the animal body.

Heat Regulation

The chemical processes involved in the capture and use of solar energy by the body all generate heat. Overheating of the body, which would finally cause heat-stroke, is normally prevented largely by the radiation of heat from the surface of the skin. Also when the body gets too hot the "temperature sense-organs" in the skin send messages up the afferent nerves to the "temperature center" in the brain stem; this in turn sends currents down the nerves to the muscular sheaths of the capillary blood vessels, causing them to become dilated and the sweat glands to pour out sweat. This, being a slightly salt solution, evaporates quickly and causes a rapid cooling of the heated blood in the skin. On the other hand, excessive loss of heat is checked in most mammals by the furry undercoat of the skin, and in man especially by the secretion of the adrenal glands; this secretion unites with the free oxygen in the blood, thus producing heat. Additional heat is generated also by shivering, but chiefly by muscular exercise.

Thus we see that man, like other mammals, possesses various mechanisms for maintaining a relatively high and stable temperature (about 98.4° Fahrenheit in man) in spite of wide variations in the temperature of the environment. The lower vertebrates (reptiles, amphibians), on the other hand, have a more variable body temperature and are more at the mercy of changes in the environment.

The Main Pump of the Body

The heart is the motor that drives the blood through all the circulatory system and keeps it on its ceaseless round. It is an automatic double pump operated by involuntary muscles and by nervous reflexes. The minute muscular engines which contract and expand this double pump are built into its walls.

The two bag-like pumps, which work in unison, are placed side by side with a single muscular partition between them (Fig. 1). The left, or SYSTEMIC HEART, sends fresh arterial blood from the lungs to the body; the right, or RESPIRATORY HEART, receives venous blood from the body and sends it to be renewed, or oxygenated, in the lungs. Each half consists of an atrium (auricle) or thin-walled receiving chamber and of a ventricle, or thick-walled pumping chamber

Thus the four main divisions of the heart are as follows: (1) the LEFT AURICLE receives freshly oxygenated or arterial blood from the lungs through the right and left pairs of pulmonary veins; when the heart expands this blood is drawn through a one-way valve from the left auricle to the left ventricle; (2) the LEFT VENTRICLE then contracts, driving the blood through the aorta to the capillaries of the head and body. Here the blood loses its surplus oxygen and after absorbing the free carbon dioxide passes from the capillaries into the veins; these drain into the upper and lower venæ cavæ, which open into (3) the bag-like RIGHT AURICLE or atrium; the latter in turn passes the blood through another valve into (4) the RIGHT VENTRICLE, which pumps it through the right and left pulmonary arteries to the lungs.

Nerve fibers are diffused through the heart muscles. At each beat contraction begins in the "pace-maker," or sino-auricular node, and spreads thence to other parts of the heart.

While the rhythmical expansion and contraction of the heart is largely automatic, the beat is retarded by branches of the vagus nerve and accelerated by branches of the thoraco-lumbar nerves of the sympathetic system. The brain centers for regulating the heart beat are in the medulla.

The Living Bellows

Air is drawn into the chest cavity and forced out of it again by rhythmical movements of the ribs and diaphragm (Fig. 3). The scalenus and intercostal muscles pull the obliquely-set ribs upward and outward, the abdominal muscles pull them forward and downward. As they move upward they rotate slightly outward and thus increase the volume of the chest cavity; this reduces the air pressure in its interior and so draws fresh air into the lungs.

The diaphragm is a muscular and tendinous dome which, with the aid of the abdominal muscles, acts both as a bellows for the chest cavity and as a piston for the abdominal cavity. When it descends the abdomen expands; when it moves upward the abdomen contracts; thus it assists the circulation of the blood in the liver and digestive tract.

In the living bellows formed by the diaphragm, thorax and abdominal muscles, the great multitude of muscular engines are built into the wall of the bellows.

In the ascending series of vertebrates from fish to man the breathing muscles of the ribs have experienced a change of function, having arisen from the lateral muscles of the body-walls, which were originally locomotor muscles. The main muscle of the diaphragm represents a backward extension of one of the ventral neck muscles of the lower vertebrates; the diaphragm as a whole is a secondary partition, completed in the mammals, which separates the heart and lungs from the abdominal cavity.

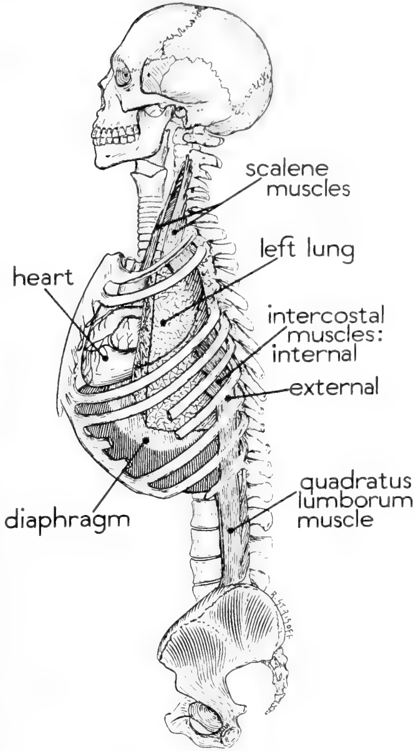


Fig. 3. The living bellows.

Sketch model showing the position of the muscles that cause the bellows-like action of the chest in breathing.

Based on data from Sir Arthur Keith's "Engines of the Human Body".

The Ductless or Endocrine Glands

(See also exhibit on opposite side of hall.)

The ductless or endocrine glands play an important part in metabolism (the breaking down and building up of the cell materials of the body), also in reproduction and in growth from infancy to old age.

The ductless glands secrete substances called hormones because they act as "chemical messengers," which are carried by the blood and activate other tissues.

Pineal. This gland represents a stalk-like outgrowth from the roof of the third ventricle of the brain. In some of the lower vertebrates it is the stalk of the pineal eye, but in the mammals, including man, it has lost its eye and shriveled into a mere remnant. In young children with diseased pineal gland the sex glands develop at a very early age and there is a precocious abnormal growth of the long bones.

Pituitary. This gland fits in the "sella turcica" or "Turkish saddle" in the middle of the base of the skull. It comprises three parts, the anterior, intermediate, and posterior lobes. The hormone of the anterior lobe, called TETHELIN, stimulates growth and the healing of wounds. Extracts of the middle and posterior lobes, containing PITUITRIN, produce a rise in blood pressure, increased activity of the kidneys and milk glands, and also stimulate contraction of the muscles of the uterus. On the other hand, pituitrin inhibits the secretions of the salivary glands, stomach and pancreas.

Deficiency in the secretion of the anterior lobe of the pituitary causes a child to become a diminutive dwarf. Early overactivity of the same gland makes him a "symmetrical" giant. If the activity begins after puberty, well rounded development is no longer possible, but the resulting overgrowth (acromegaly) takes place only in such parts of the body as are still susceptible to the influence of the hormone. The pituitary body is found in all the vertebrates.

The pituitary gland is of complex origin. In the human embryo the anterior lobe originates from a pouch-like projection of the outer layer of the embryonic mouth or stomodeum. The posterior lobe originates from the base of the mid-brain.

Thyroid. Chemical analysis of the thyroid gland reveals the presence of compounds of carbon, hydrogen, oxygen, nitrogen, sulphur, phosphorus, sodium, calcium, iodine and other elements.

Thyroxin, the most widely known derivative of the thyroid gland, is a crystalline body with a relatively high iodine content. Extremely

small quantities of thyroxin stimulate metabolic processes, while a deficiency of thyroxin is one of the causes of cretinism, myxoedema and other abnormal conditions.

"Hyperthyroid" persons have an excess of thyroid secretion and are extremely energetic. In "hypothyroid" persons the opposite symptoms appear.

PARATHYROIDS. These small glands, although closely associated with the thyroid, have a different function. They are indispensable for the assimilation of calcium. In rabbits from which the parathyroids have been removed the bones become soft and brittle and the teeth break easily, since they lack calcium. Complete removal of human parathyroids causes a tetany followed by death.

THYMUS. This "gland of childhood" is also highly necessary for the building of bone, especially the long bones of the limbs. The thymus shrinks when the sex-glands develop and becomes very small or vestigial in normal adults.

The thyroid, parathyroids and thymus are derived from different pockets of the embryonic gill structures.

SUPRARENALS. These glands are hat-like bodies, one on top of each kidney. The sponge-like medulla, or core, of the suprarenals forms adrenalin, or epinephrine. One part of adrenalin in four hundred million parts of water checks the action of the intestinal muscles, makes the heart beat faster, causes the liver to discharge its glycogen and prevents fatigue. The suprarenals have thus been called the "fighting glands." Adrenalin also inhibits the action of insulin from the pancreas. The cortex, or rind, of the suprarenals contains many delicate blood vessels, fat droplets, blood spaces and cells containing dark fatty pigments.

In Addison's disease the cortex of the suprarenals is affected so that an excess of dark brown pigment is deposited in the skin and the mucous membranes.

ISLANDS OF LANGERHANS. These very minute glands in the pancreas secrete insulin, a hormone indispensable for the "combustion" of glucose in the production of muscular energy.

SEX-GLANDS. The primary sex-glands (ovaries in females, testes in males) begin to appear at an early stage of embryonic development and to produce "hormones" which determine the subsequent development of either the female (egg-producing) or the male (sperm-producing) sex. In the males the secretions of the interstitial glands of the testes produce certain male characters. In the females the secretions of the yellow-bodies (corpora lutea) of the ovaries affect various changes in the uterus during menstruation and pregnancy.

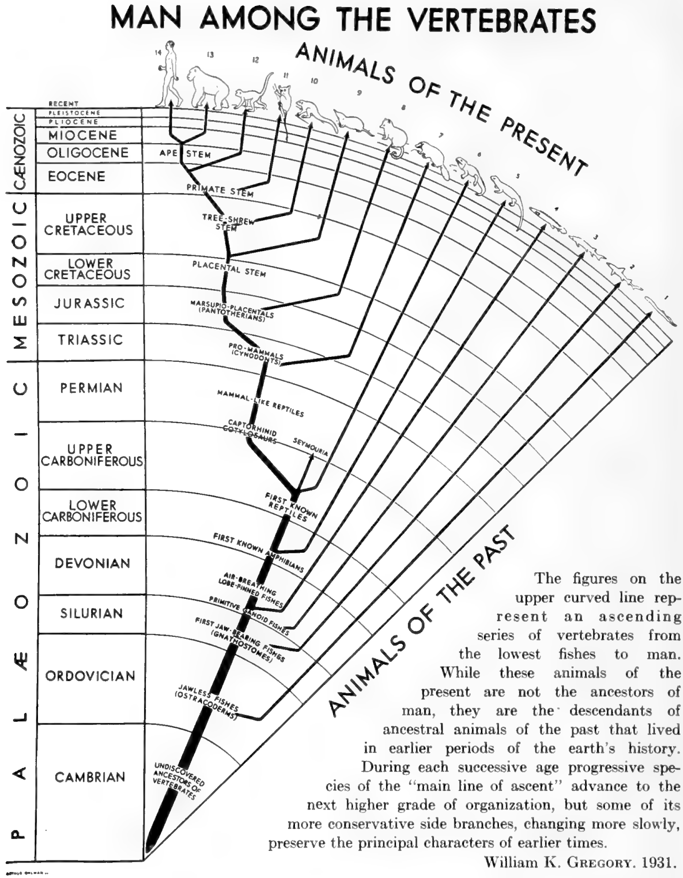


Fig. 4. Man among the vertebrates (Wall Chart 2).

1. Lamprey. 2. Shark. 3. Sturgeon. 4. *Polypterus*. 5. Newt. 6. *Sphenodon*. 7. Platypus. 8. Opossum. 9. Ground Shrew. 10. Tree Shrew. 11. *Tarsius*. 12. Monkey. 13. Anthropoid. 14. Man.

ORGAN SYSTEMS OF SHARK AND MAN

[Case IIA]

Man, like other animals, captures and utilizes the life-giving energy of the sunlight (contained in food) by means of a complex anatomical equipment, which includes the following systems:

(1) The Alimentary System
(Mouth, jaws, teeth, tongue, digestive tract, salivary glands, liver, pancreas, etc.)

(2) The Blood-Stream System
(Red corpuscles, white corpuscles, blood platelets manufactured in the spleen, marrow, and elsewhere)

(3) The Circulatory System
(Heart, arteries, capillaries, veins, lymphatics)

(4) The Respiratory System
(Lungs, windpipe, bronchial tubes, breathing muscles)

(5) The Motor System
(Locomotor muscles, bones, joints, ligaments, etc.)

(6) The Excretory System
(Kidneys, bladder, skin)

(7) The Heat-producing and regulating System
(Temperature receptors in skin, sweat glands, etc.)

(8) The Endocrine or Ductless Gland System
(Thymus, thyroids, parathyroids, pituitary, adrenals, etc.)

(9) The Receptor System
(Sense organs, afferent nerves and nerve centers)

(10) The Autonomic Nervous System
(Sympathetic and parasympathetic nerves, plexuses and their connections)

(11) The Central Control System
(Spinal cord, brain, etc., controlling the motor system and coördinating all other systems)

(12) The Reproductive System
(Ovaries, testes and associated parts)

Digestive System. In both shark and man the digestion and absorption of food takes place in a long winding tube, the alimentary canal or gut; this is subdivided into œsophagus, stomach and intestine, and bears as appendages a liver and a pancreas. In both cases the stomach secretes an enzyme and a small quantity of hydrochloric acid. The other main divisions likewise secrete several enzymes or ferments, which split up the food into glucose, glycerol, fatty acids, amino-acids, etc., and thus prepare it for absorption by the capillary blood-vessels in the wall of the gut.

Although the shark's gut is thus an epitome of that of man, it also has certain peculiarities. Its stomach is subdivided into a swollen cardiac portion, separated by a valve from the tubular pyloric section; the intestine is filled with a great spiral fold, which greatly increases the absorptive area.

Circulatory and Oxygenating Systems. The circulatory and oxygenating systems in both shark and man have the same functions, namely:

(1) to deliver to all parts of the body the energy-bearing food products from the digestive system;

(2) likewise to distribute everywhere the oxygen-bearing red blood corpuscles;

(3) to deliver the waste products to the excretory system.

In both shark and man the main muscular pump, or heart, drives the blood to the capillary vessels of the body, whence the veins return it to the heart, whence the heart sends it respectively to the gills or to the lungs. In the shark, however, the heart is a relatively simple pump, consisting of auricle, ventricle and conus arteriosus arranged in a fore-and-aft series; these drive the blood forward to the gills. In man, as in other mammals, a median partition divides the heart into a double or four-chambered pump, the right side sending venous blood to the lungs, the left, pure blood through the aorta to the body (See Case I). Intermediate conditions are found in lung-fish, amphibians, reptiles and in the embryonic stages of man.

In a human embryo 4 millimeters long the shark-like ground-plan of the human circulatory system is more evident than in the adult. In the shark the aortic arches give off vessels to the gills; in the human embryo gills are absent but the gill-pouches, which are still represented (See Case 18), are likewise supplied by aortic arches. The heart of the human embryo is also simpler, more shark-like, than in the adult.

COMPARATIVE ANATOMY OF THE HEART. The four-chambered heart of man is constructed on the same plan as that of other mammals, but in some of the lower vertebrates, especially the amphibians, the right and left halves are more or less incompletely divided from each other, so that the venous and arterial blood are mingled in the single ventricle. In the shark, representing primitive fishes, there is no median partition of the auricle and ventricle; in other words, the heart is single not double.

The transition from the single to the double-chambered heart is seen in the developmental stages of the heart of man and other mammals.

URINOGENITAL SYSTEM. In *Amphioxus*, the most primitive known pre-vertebrate, the waste products of the blood are excreted through about ninety pairs of small nephridia, or bent tubes situated above the pharynx. The gonads (producing eggs or sperm respectively) are about twenty-six pairs of pouches arranged metamerically (in series) along the body wall. Thus the excretory and reproductive systems are separate in this very primitive type.

In the shark and higher vertebrates, however, the excretory tubules are united into a pair of organs, the kidneys, and the organs of excretion and of reproduction form a complex urino-genital system.

Each kidney consists of an immense number of coiled tubules, forming a "living high-pressure filter" that separates the clear blood plasma from the nitrogenous wastes, including urea, that have been received from the liver, etc., by way of the blood-stream. The kidneys also help to maintain the proper volume and composition of the blood partly by eliminating excess water, and rid the body of undesirable salts and foreign substances in the blood.

In the females of the lower vertebrates the ova, or eggs, after escaping from the ovaries are usually carried out by separate right and left oviducts. In the primates, including man, the lower parts of these ducts are united into a median thick-walled pouch, the uterus or womb, in which the fertilized egg develops into an embryo (Fig. 20).

In the males of many of the higher mammals, including man, the testes, containing the spermatozoa or male elements, descend during individual development (i.e., before or after birth) from the abdominal cavity into a pouch, or scrotum. Hence the ductus deferens through which the spermatozoa pass out, ascends from the testis, looping over the ureter or tube from the bladder and opening into the urethra. Thus in the higher mammals, including man, the male genital products and the urine pass out through a single tube, the urethra.

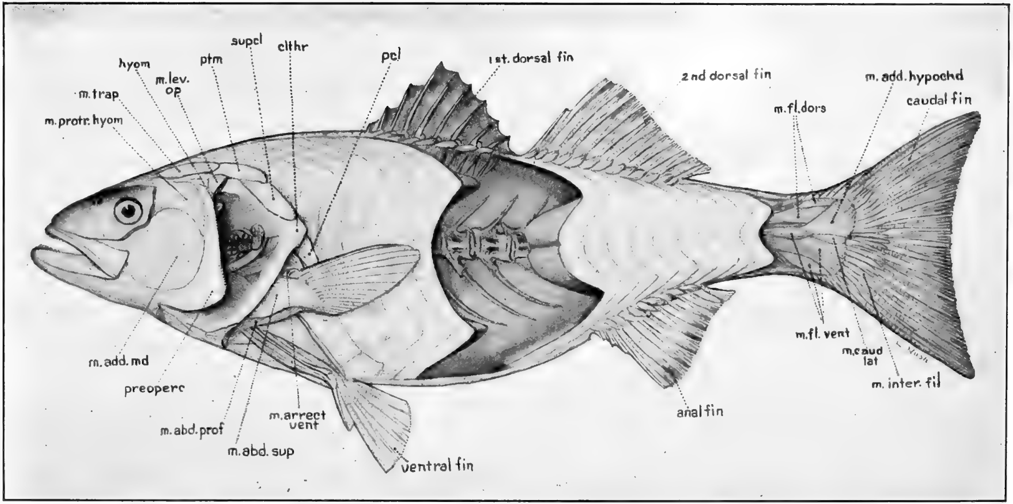


Fig. 5. The locomotor apparatus of a typical fish (striped bass).

The myomeres or muscle segments are arranged in zigzags closely fitting one behind the other. These are the main locomotor organs of the fish, the fins being of secondary importance.

Drawn from dissections by M. Roigneau.

Elements of the Locomotor System

[Case IIB]

To explain how a man moves we begin with a fish. A fish moves through the water by turning his head first to one side, then to the other, and by sending one wave of contraction after the other along his tapering body. As these muscular waves flow backward they push against the water and drive the fish forward.

The body muscles of fish and other vertebrates are arranged in segments, one behind the other (Fig. 5). Immediately after the segment on one side contracts the nerves carry the message up to the spinal nerve cord and thence downward to the next segment on the same side; another set of nerves carries the message to the other side and starts a wave going on that side; and so on.

The human embryo passes through a stage in which the somites or segments are arranged in a fore-and-aft series, like the locomotor segments of a fish.

Although the muscle fibrils are so minute that the human body contains many billions of them, they are composed of molecules and atoms which are incomparably smaller still. When a muscle contracts it does so because its nerve fibres have discharged into it a current of some sort which suddenly upsets the equilibrium of the muscle's atoms and molecules. A chemical reaction takes place, the molecules shrink, causing contraction of the muscle, and lactic acid is set free in the tissues. Some of the oxygen carried by the red blood corpuscles is then used in restoring the muscle molecules and in oxidizing the waste products.

The Backbone. The backbone arose as a flexible elastic rod (the notochord), which enabled the fish to thrust its undulating body forward through the water. As time went on the notochord became strengthened by bony rings or centra, which, being separated by elastic discs, enabled the backbone to bend. Bony arches were added to protect the spinal nerve cord.

In man the backbone, held at right angles to its original position, supports the skull, ribs and internal organs.

Vertebræ, or units of the backbone, are the essential and original core of the skeleton of vertebrates, or animals that are provided with a backbone, or vertebral column.

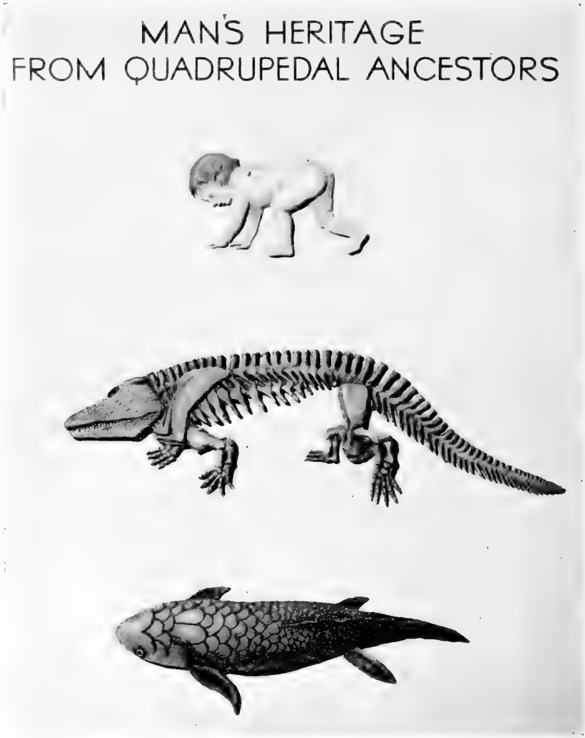


Fig. 6. Man's heritage from quadrupedal ancestors.

Below. Air-breathing fish (*Ceratodus*) with paired paddles. After Dean.
Center. Fossil amphibian (*Eryops*) from the Permian of Texas.
Above. Human infant running on all fours. After Hrdlička.

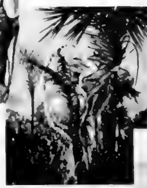
Note the comparison between the paired paddles of the fish, the fore and hind limbs of the quadruped and the arms and legs of man.

STUDENTS IN NATURE'S TRAINING SCHOOL

Neanderthal cave-man

Miocene anthropoid

Early lemuroid primate



Archaic mammal

Cynodont reptile

In the present and past ages of the earth Nature has kept a physical and mental training-school of many grades. Her examinations have always been practical ones, the prize of survival being awarded to the "fittest" in each successive grade.

In the primary school the lower grades were passed through under water. Here one learned to swim and steer in the currents, to lurk quietly, to strike successfully. A few grades further on the pupils were equipped with air-sacs, so that they could wriggle out on the banks and use their fore-and-hind paddles as limbs.

After acquiring the physique to withstand hardships of heat and cold, some of the more advanced candidates were admitted to the school of the forests and to the uncertainties of life in the trees, where a practical course in the care and feeding of infants was required of all mothers.

At last the most intelligent pupils ventured out into the open and went into training both for short sprints and cross-country runs. In their manual training schools they learned the art of making flint implements and weapons and with these, before they retired to their dormitories at night, they prepared for themselves their simple meal of bear's meat.

Thus they were trained for the degree of H. S. (*Homo sapiens*), which was eventually won by their descendants.

W. K. Gregory, 1931.
F. L. Jaques, pinx.

Primitive terrestrial reptile

Generalized amphibian

Lobe-finned fish

Primitive ganoid fish

Fig. 7. Students in Nature's training-school (Wall Chart 3)

Fig. 8. The skeleton from fish to man

A. Primitive ganoid fish, *Cheirolepsis,* Old Red Sandstone (Devonian). Models based on fossils described by A. S. Woodward, D. M. S. Watson.

B. Lobe-finned fish, *Eusthenopteron,* Upper Devonian. Models based on fossils described by W. J. Bryant, D. M. S. Watson.

C. Generalized amphibian, *Diplovertebron,* Lower Carboniferous. Models based on fossils described by D. M. S. Watson.

D. Primitive reptile, *Seymouria,* Lower Permian, Texas. Models based on fossils described by S. W. Williston, F. Broili, D. M. S. Watson.

E. Cynodont reptile or pro-mammal, *Cynognathus,* Upper Triassic, South Africa. Models based on fossils described by H. G. Seeley, R. Broom, D. M. S. Watson and others.

F. Archaic mammal, Opossum, Recent, North America. Survivor of an Upper Cretaceous marsupial mammal described by W. D. Matthew.

G. Very ancient Primate, *Notharctus osborni,* Middle Eocene, Wyoming. Models based on fossils described by William K. Gregory.

H. Brachiating anthropoid, Gibbon, Recent. Specialized long-limbed derivative of primitive anthropoids.

I. Typical anthropoids, Chimpanzee (above) and female gorilla (below).

J. Man.

The Skeleton from Fish to Man

[Case III]

The skeleton of man, like that of all other vertebrate animals, is the passive part of the locomotor machinery, while the muscles and nerves are the active part. Comparative study of the skeletons of all known types of fossil and modern animals has made it possible to decipher the record of progress from fish to man. The series of forms here shown (Fig. 8) does not form a DIRECT line of descent from fish to man but each stage shown is the nearest to the direct line so far discovered.

The earliest vertebrates lived exclusively in the water and swam by undulating the body. The fins were projections of the skin and body wall that served chiefly as rudders and balancers (Stage A). Gradually, in the swamp-living, air-breathing fishes the pectoral and pelvic fins were transformed first into paddles (Stage B) and then into limbs (Stage C) as the animals crawled out of the swamps. After many ages the animals invaded the uplands (Stage D), learning to crawl like turtles and lizards.

Next, they learned to raise the belly off the ground and run about (Stage E). Then they climbed up into the trees and became very expert in running and leaping about among the branches (Stages F, G, H).

At first these tree-living animals ran about mostly on top of the branches (Stage G). Then some of their descendants adopted the "suspension grasp," as they began to swing from branch to branch. The gibbon, Stage H, is rather overspecialized in this direction.

Avoiding extreme overspecialization for "brachiation" (swinging with arms) the ancestors of man came down from the trees, running perhaps occasionally on all fours but more and more often erect, as do the gibbons when on the ground.

From his prehuman anthropoid ancestors, which were related to the chimpanzee (I, upper) and the gorilla (I, lower), man has inherited his ability to hold the body erect or balanced on the hind legs (Stage J). The fore-limbs, being relieved from their former function as locomotor organs, were set free to serve the enlarging brain in defending the body and providing for its needs.

The Upright Posture and its Maintenance

[Case IVA]

From fish to man there is still a chain of living forms, in spite of all the devastation and wholesale extinction of the present and past

ages. As the skeleton of man testifies to his derivation from lower forms of vertebrates (Fig. 8) so also does his muscular system; and through this orderly and intelligible series of stages we can follow the main changes of posture as our ancestors learned first to swim, then to crawl, to run, to climb and finally to walk erect.

In the swimming stages (see Fig. 8A, B) the segmental muscles of the backbone and ribs were dominant, the fin-muscles being subordinate extensions of the body. Then the paddles grew outward (C) and were eventually moulded into the new and highly organized limbs of land-living vertebrates (D-J).

These limbs are compound levers with the muscles arranged on opposite sides of the pivots and acting in pairs as antagonists to produce extension or flexion, abduction or adduction, twisting and untwisting, etc. In walking and running each limb alternately pulls and pushes on the ground. When in early stages the limbs sprawled widely at the sides, the limb muscles were very thick. In the course of ages, as the feet were gradually brought in toward the midline and the body was raised off the ground, the limbs grew longer and more graceful.

The Superficial Musculature of the Chimpanzee. When running on the ground the chimpanzee usually goes on all fours, supporting the fore part of the body on the fingers, sharply bent at the middle joints. The muscular anatomy, however, is well adapted also for a semi-erect posture, as well as for sitting upright and for brachiating, or swinging with the arms (Fig. 9).

Among the more conspicuous differences from man are: the very short neck, the long arms and short legs, the long fingers, the short thumb and the inwardly-directed great toe. The loins (lumbar region) are extremely short and broad, the hip bones (ilia) long. The hind limb is habitually flexed at the hip and knee.

There are corresponding differences in the proportions of the muscles: for example, the limb muscles of the chimpanzee are more fleshy, with shorter tendons, than in man. A peroneus tertius muscle is usually lacking.

These and many other such differences between chimpanzee and man relate to the wide contrast in their PRESENT methods of locomotion; but in spite of these adaptive differences there is a remarkable unity in the plan and arrangement of the muscles in these two forms.

Man. Man is a fully erect bipedal mammal whose entire weight is carried by his long hind limbs (Figs. 8J, 9). Consequently his

Fig. 9. Muscular anatomy of chimpanzee and man, showing principal muscles used in maintaining upright posture.

The model of the chimpanzee, by G. D. Christensen, was based on dissections by H. C. Raven.

superficial glutæal muscles are relatively enormous as compared with those of the chimpanzee, since they assist alternately in holding the body aloft on one side, while the opposite leg swings off the ground.

For similar reasons his erector spinæ muscles are much widened, especially at the lower end, his gastrocnemius muscle is very thick and short with a long tendon, and the biceps femoris muscle extends only a little way below the knee.

His long loins (lumbar region) form a flexible lever on which the whole weight of the upper part of the body is poised. In order to give better balance the back is curved in at the lumbar region and the hip bones are widened greatly.

Another consequence of the upright posture is that the fore limbs of man are completely suspended from the skull, the backbone and

the ribs, since they no longer serve as limbs but as levers for moving things.

In spite of these and many other special adaptations to the upright posture, man has inherited from his remote pre-human ancestors a great many characters which have also been retained in the existing anthropoid apes. For example, his shoulders are held far away from the neck by means of the long curved clavicle, his arms can be swung around in a complete circle, his hands can be freely turned up, or supinated; his thumb, however, has progressed beyond the grasping stage that is now represented in the ape's thumb.

The Pectoral and Pelvic Girdles

[**Case IVB**]

A well-known dictionary defines the term girdle in the anatomical sense as "The ring-like arrangement of bones by which the limbs of a vertebrate animal are attached to the trunk." The pectoral and pelvic girdles might better be defined as originally U-shaped or V-shaped bony supports by which the trunk is suspended between the limbs (Fig. 12).

In the oldest and most primitive known fossil fishes the body moved forward through the water by waving from side to side by means of the contraction of successive muscle segments (Fig. 10). At that time the fins were merely keel-like projections from the body, which were stiffened internally by rod-like skeletal supports, and externally by spines formed in the skin. All the fins functioned as keels and rudders rather than as paddles. Between the pectoral and the pelvic fins in certain primitive fishes there were several other pairs of fins. Evidently the paired fins were similar both in origin and in construction to the median or unpaired fins.

The fins in ancient and modern sharks were supported by skeletal rods which were laid down in the membranes between adjacent muscle segments.

The anal, pelvic and pectoral fins of early fossil sharks (Fig. 10) exhibit progressive stages in the squeezing together of the basal rods into a U-shaped girdle.

The subsequent history of the shoulder girdle from fish to man is summarized in Figs. 11-13. In typical fish the pectoral girdle consisted of: (1) an outer or dermal series of bony plates (including the cleithra, clavicles, etc.) and (2) an inner or primary shoulder girdle, including the scapula and coracoid.

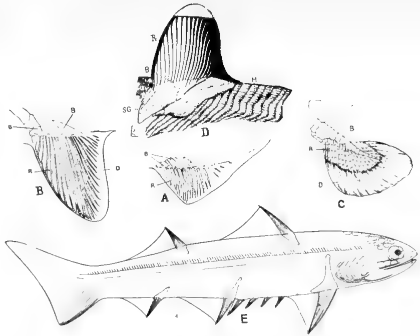


Fig. 10. Earliest known stages in the origin of the fins and girdles.

A. Ventral fins of Devonian shark (*Cladoselache*), showing separate rod-like supports of "fin-fold" fin.

B. Pectoral fin of *Cladoselache*, showing pectoral girdle and basal pieces presumably derived from fusion of separate rods.

C. Pectoral fin of Permian *Pleuracanthus*, showing fully developed paddle-like fin with jointed axis.

D. Pectoral fin of *Cladoselache*, partly covered by preserved myomeres.

E. Restoration of generalized acanthodian by Dean.

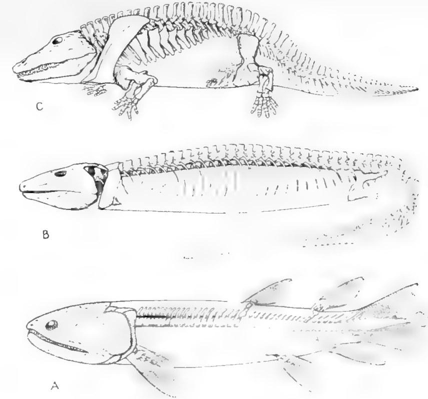


Fig. 11. The shoulder girdle, originally attached to the skull by a bony link, becomes free from it in land animals.

A. Reconstructed skeleton of *Eusthenopteron foordi*, based on the data of Bryant, Hussakof, Goodrich

B. *Eogyrinus*. Reconstruction slightly modified from Watson.

C. *Eryops megacephalus*. Based chiefly on the mounted skeleton in the American Museum of Natural History. Details of pectoral [illegible] and limb after Miner.

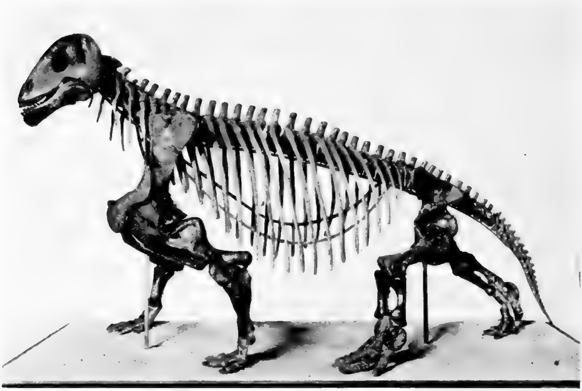


Fig. 12. Skeleton of *Moschops capensis* Broom.

In this fossil mammal-like reptile the shoulder girdle retained the cleithra (reduced), clavicles and interclavicles, representing the outer layer of the fish girdle, and the coracoids and scapulae (shoulder blades) of the inner layer of the fish girdle.

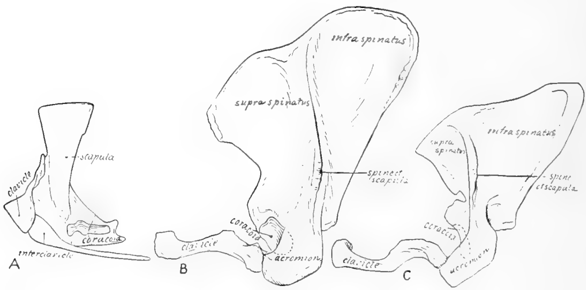


Fig. 13. In higher mammals the shoulder girdle consists on each side only of a shoulder blade (scapula) and a collar bone (clavicle), the remaining parts having been lost.

A. Typical early reptilian type, after the loss of the cleithrum.

B. Gorilla. C. Man.

The shoulder girdle of man is very like that of the gorilla.

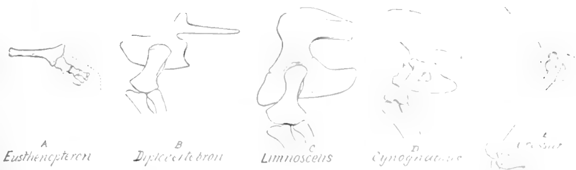


Fig. 14. Series of pelves and pelvic limbs, from lobe-finned fish to primitive mammal.

The pelvis (Figs. 14, 15) arose as a pair of bony rods on either side of the cloaca, or exit of the digestive and reproductive tubes. It supported the pelvic fins. After the lobe-finned fishes came out on land the iliac blades of the pelvis grew upward, becoming attached to the sacral ribs and thus to the vertebral column.

A. Lobe-finned ganoid (*Eusthenopteron*) of the Devonian period; B. *Diplovertebron*, early tetrapod; C. *Captorhinus*, primitive reptile; D. *Cynognathus*, advanced mammal-like reptile; E. Opossum, primitive mammal.

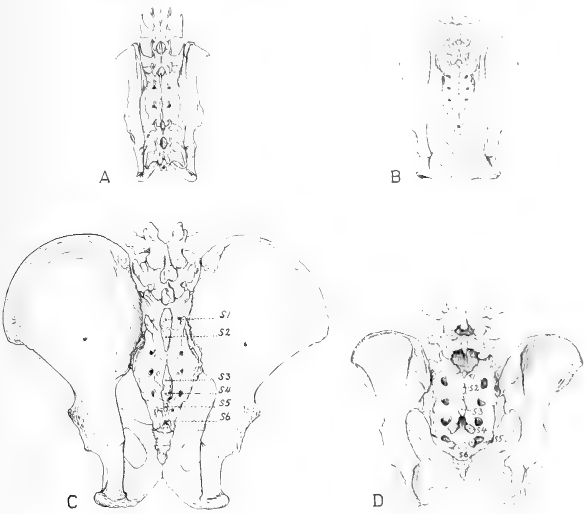


Fig. 15. Progressive widening of the pelvis and sacrum in primates.

A. Lemur, with long narrow ilia adapted for leaping.

B. Gibbon. Incipient widening of the iliac blade.

C. Gorilla. D. Man.

Hands and Feet

[Case VA]

Hands of Primates. The hands and feet of most mammals are provided with digits that are tipped with either claws or hoofs; but in the primates the digits usually bear nails. These nails appear to be relics of an ancient arboreal habitus, which, as the fossils show, had already been assumed by the early primates of the Eocene epoch. The most primitive existing primates are the lemurs of Madagascar, which have a strongly grasping type of hand with the fourth digit the longest and partly opposable to the thumb. In the most specialized of the lemurs, the potto of Africa, these characters are greatly emphasized, while the second finger has become vestigial. (Fig. 16.)

The hand of *Tarsius* retains the primitive five digits but the ends of the fingers bear large flattened discs like those of tree-frogs.

The New World monkeys, or platyrrhines, exhibit considerable skill in handling objects and their hands are more mobile and less clamp-like than those of lemurs. Most of these animals have five-fingered hands, but in the spider monkeys, which use the hands as hooks to swing with, the thumb is lost.

In most of the South American monkeys the nails are strongly folded; in the marmosets this tendency gives rise to false claws.

In the Old World monkeys, or catarrhines, the hands are intermediate between paws and true hands. In the species of *Colobus* monkeys the thumb is variously reduced, sometimes almost to the vanishing-point, doubtless in connection with the use of the hands as hooks.

In most of the anthropoid apes the hands have become elongate and specialized, with a more or less feeble thumb. These tendencies terminate in the orang-utan. In the gorilla the hands are very broad and massive, in keeping with the burly proportions of the body as a whole. In man the hand far surpasses those of other primates as an organ for picking up food and other things. The thumb is larger than in the anthropoids and is more easily opposable to the other digits.

However, the human hand inherits a generally anthropoid type of musculature and the thumb springs from the root of the hand as in the anthropoids, not from near the end of the metacarpals as in Old World monkeys.

Fig. 16. Hands of Primates. Man inherits a five-rayed plan of the hands and feet, which has been specially modified so that the fore feet ordinarily have to do only with the handling of objects.

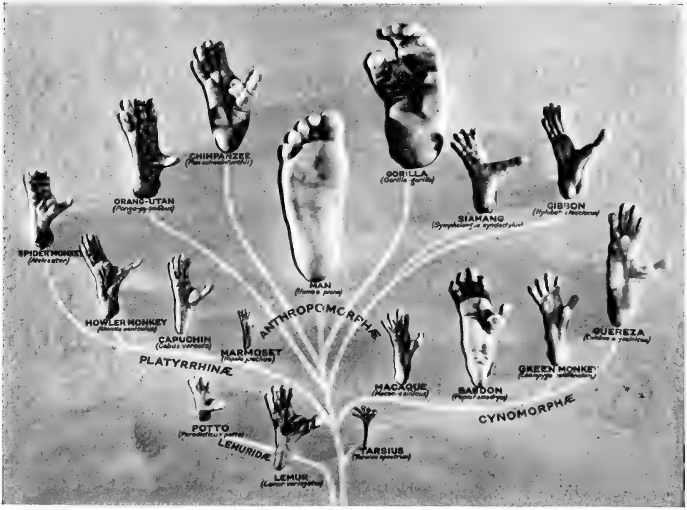


Fig. 17. Feet of Primates. Casts showing the sole of the foot. In the lower primates the big toe branches off at a sharp angle from the rest of the foot but in man it has been drawn forward so as to be nearly parallel with the other toes.

Feet of Primates. The five-toed feet of the lemurs have a large sharply-offset great toe tipped with a broad flat nail (Fig. 17). The clawed second digit is used for scratching the fur. The long fourth digit coöperates with the great toe in firmly clamping the branches. In the foot of the potto these grasping characters are further emphasized. In *Tarsius* the foot is spreading, with delicate digits, flattened discs and more or less clawlike nails.

In the New World monkeys the foot is more mobile, less clamp-like than in the lemurs, and the same is true in the Old World monkeys, although all retain the divergent great toe.

In the anthropoid apes the foot is often used for suspension, especially in the orang-utan, in which the foot becomes extremely long and narrow. In the gorilla the toes have begun to shorten and the great

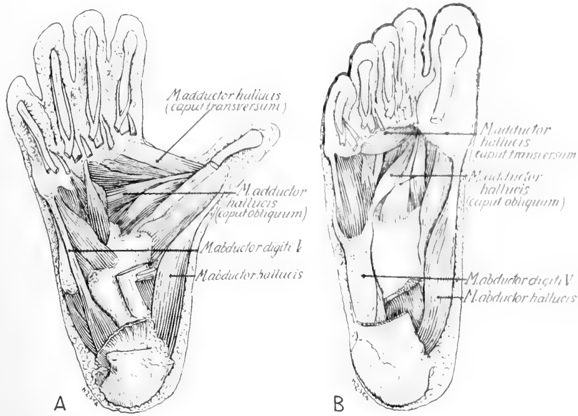


Fig. 18. Grasping muscles of the great toe and their opponents as seen on the sole of the foot in (A) Gorilla; (B) Man. After dissections by H. C. Raven.

In man the transverse adductor of the great toe is still present essentially in the anthropoid position though much reduced. The oblique adductors of the great toe are well developed in both man and anthropoids.

The abductor of the great toe is almost identical in man and anthropoids. The same is true of the abductor of the little toe.

toe begins to resemble that of man, except that it is still off-set from the other digits. In the orang, chimpanzee and gorilla the heel is placed on the ground in walking, as in man.

In man the great toe has become drawn in toward the other digits and the latter have become very short.

Comparative Anatomy of the Sole of the Human Foot. The superficially hand-like appearance of the feet of the chimpanzee and gorilla was viewed in earlier times as an important and fundamental point of difference from the foot of man, but dissections of the sole musculature show that the foot of the chimpanzee and the gorilla is operated by muscles which correspond, not to the muscles of the human hand, but to those of the human foot (Fig. 18). In brief, the musculature as well as the skeleton of the human foot is fundamentally of the biramous anthropoid type.

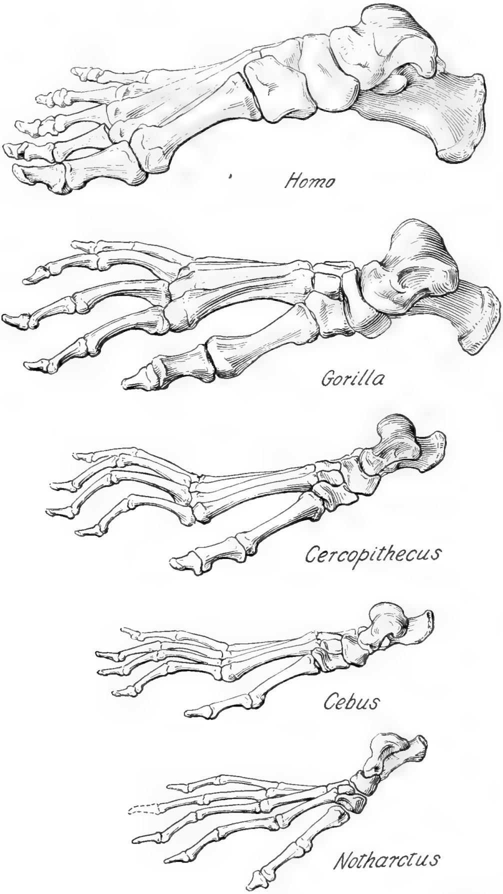


Fig. 19. A structural series of feet of primates from the Eocene *Notharctus* to Man.

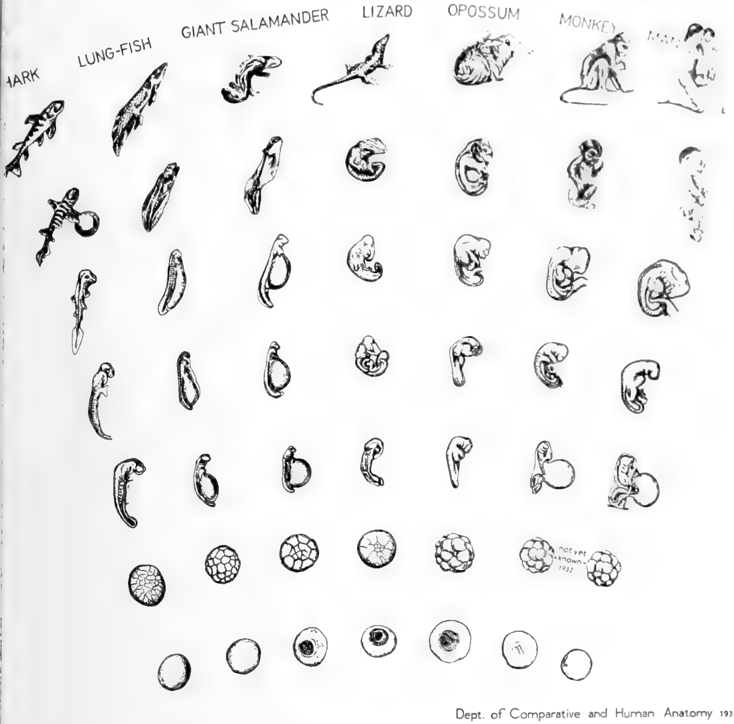


Fig. 20. Comparative embryology from fish to man (Wall Chart 5).

Man, like other vertebrates, develops from a zygote or fertilized egg, which divides and subdivides as it grows until it eventually gives rise to the millions of cells in the adult body.

In order to facilitate comparison the corresponding stages in the different lines of development have been enlarged to about the same size, regardless of 'scale.' Thus the human egg, which measures only about 1/250 of an inch in diameter, is here shown nearly as big as the egg of the Port Jackson shark, which measures about two inches (bottom row).

The picture shows seven out of the innumerable stages of development.

The second row illustrates late cleavage stages. In the third row note the beginning of somites (body segments); in the fourth row gill slits and the beginning of the fore limbs are indicated; the fifth row shows late embryos with fore and hind limb buds; sixth row, late foetal, newly hatched, or new-born stages; top row, adults.

THE FACE FROM FISH TO MAN

[Case VI]

A comparative series of models, including living and extinct forms and showing a general progress from fish to man (Fig. 21).

These forms do not lie in the direct line of descent to man but are the nearest to the direct line yet discovered.

The lower forms contrast with man in the following characters:

	LOWER FORMS	MAN
Normal position of backbone	Horizontal	Vertical
Position of eyes	On side of head	In front
Direction of eyes	Outward, forward and upward	Forward and slightly downward
Position of mouth	Largely in front of eyes	Largely beneath eyes
Direction of mouth	Somewhat downward	Horizontal
Muzzle	Large	Much reduced
Nose	Not lifted above muzzle	Prominent, narrow
Nostrils	More or less separated	Close together
Upper lip	Separated by nose	Continuous beneath nose

Intermediate stages in the shifting and development of the parts of the face are seen in the monkeys and apes.

Taken as a whole, the series indicates that in the earlier forms the braincase was low; the forehead first begins to be lifted up in the monkeys but it is not until man himself appears that the brain swells up to produce an almost vertical forehead.

The eyes first appear on the side of the head and gradually shift around to the front, so that by the stage of the anthropoid ape they can both be focussed at once on an object held in the hand or near the face.

The nostrils also are originally wide apart and come together into a true nose only in the anthropoid stage. The nose is at first not differentiated from the projecting muzzle, but in the anthropoids it becomes separated from the mouth by the broad upper lip and begins to take on its human character.

The mouth is at first only the opening to a sort of fish-trap set with sharp teeth, but in the anthropoids it becomes adapted for a diet chiefly of tender shoots and herbs. In man the mouth finally becomes relatively very small and delicate.

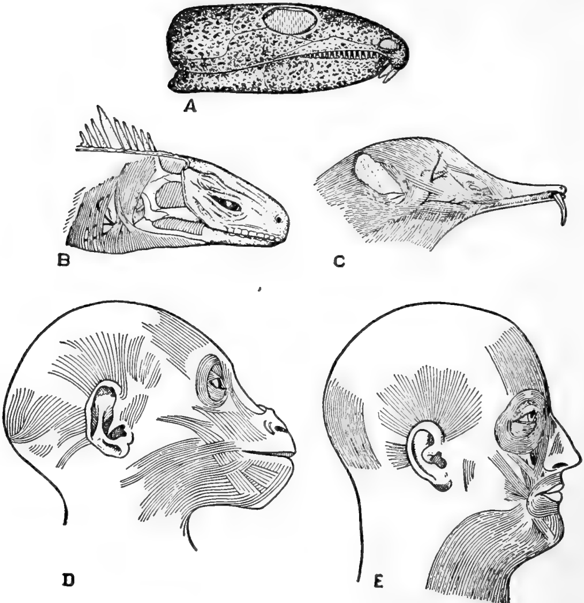
Fig. 21. A comparative series of casts and models including living and extinct forms and showing a general progress from fish to man.

Thus the face has undergone great changes in adaptation to successively different modes of life; but, from first to last, the mouth, which is the gateway to the stomach, has been assisted by the nose, the eyes, and the ears. And as our brains have improved, our eyes and ears have told us more and more about the world of nature and of men.

The Facial Muscles from Fish to Man

[**Case VI**]

The human face owes to its facial muscles the ability to smile or to frown and to express such emotions as joy, fear, dislike and their opposites. The facial muscles also take part in other movements of the lips, mouth, nostrils, ears and scalp. In mammals, including man,



Courtesy G. P. Putnam's Sons

Fig. 22. Origin of the Facial Muscles of Man.

A. Primitive reptile with continuous bony mask covering skull. The mask was covered with thick skin without muscles, as in the alligator. (After Williston.)

B. Modern reptile with an open or fenestrated skull covered with thick, non-muscular skin. (From Fürbringer, modified from Ruge.)

C. Primitive mammal in which the sphincter colli system has grown forward over the face.

D. Gorilla. E. Man. (C, D and E after Ruge.)

they extend over the face and around the scalp, ears and neck; but in the vertebrates below the mammals they are confined to the neck and throat.

The present series of models in low relief illustrates some of the steps by which the complex conditions in mammals are believed to have arisen out of the more simple conditions in man's less progressive relatives. The models (except No. 3) are based on a few of the numerous dissections and illustrations prepared by the late Professor Ernst Huber of Johns Hopkins University and described by him in his book on "The Evolution of Facial Musculature and Facial Expression" (1931).

Evolution of the Human Skull

[Cases VI, VIIA and 20]

During the evolution of the skull from that of a primitive lobe-finned fish to that of man (Fig. 24), many changes have taken place in the number, proportions and relations of the bones.

In the skull of the primitive Devonian fish, *Eusthenopteron*, there are about 145 bones, while in man (Fig. 23) the number is reduced to 27 or fewer. In the living codfish the skull is made up of 68 bones, not including the hyoid and branchial arches.

This reduction in number, as well as the striking great increase in the size of the brain-case and the reduction in the size of the jaws, well illustrates the principle recognized by Stromer and Williston, that as we pass from primitive to specialized vertebrates the number of primary skull elements is reduced, while those that remain become more highly differentiated.

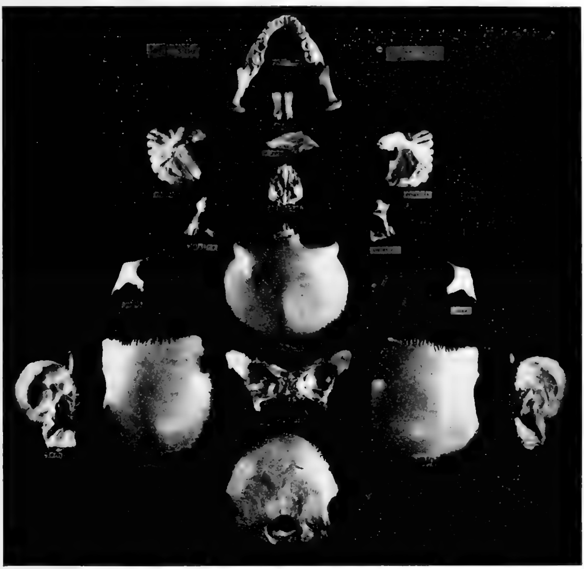


Fig. 23. Disarticulated human skull, exclusive of hyoid and laryngeal elements.

Fig. 24. Evolution of the human skull.

This exhibit is designed to show ten structural stages in the evolution of the skull from fish to man, represented by known fossil and recent specimens.

I. Devonian crossopterygian fish, *Rhizodopsis*.
II. Carboniferous amphibian, *Eogyrinus*.
III. Permo-Carboniferous reptile, *Seymouria*.
IV. Permo-Carboniferous theromorph reptile, *Mycterosaurus*.
V. Permian reptile, *Scymnognathus*.
VI. Triassic cynodont reptile, *Ictidopsis*.
VII. Recent opossum representing Upper Cretaceous marsupials.
VIII. Eocene primate, *Notharctus*.
IX. Recent anthropoid, chimpanzee.
X. Man.

Evolution of Jaw Muscles. The temporal and masseter muscles of man are homologous with similarly situated muscles in lower animals (Fig. 25). The temporal muscle arises on the side of the skull, passes down beneath the cheek arch and is inserted into the upper part of the mandible. The masseter arises from the lower border of the cheek arch and is inserted into the outer, rear part of the mandible.

In the shark (I) the temporal and masseter are represented by part of the adductor mandibulæ mass, which in turn is in series with the deep flexor muscles of the gill arches.

The temporal muscle has played a prominent part in the perforation of the bony shell behind the eyes to form the temporal opening and cheek arch (see "Evolution of the Skull").

The two pterygoid muscles (external and internal) although usually small in the mammals are of great importance in the opening and closing of the jaw. They also counterbalance the pull of the masseter, which might tear the jaws apart at the symphysis.

The digastric muscle of mammals is a compound muscle and it, together with one of the muscles of the throat region, represents part of the second constrictor of the fishes.

Fig. 24—(Continued)

Column A.—Evolution of the skull roof. The paired nasal, frontal and parietal bones of the primitive vertebrates (I–V) are passed on by heredity to the lower mammals (VII, VIII) and finally to man (X). In man (top) the upgrowth of the brain is reflected in the dome-like cranium.

Column B.—Evolution of the bones around the eye. In lower vertebrates (I–V) there was a series of five bones around the orbits or eye-sockets. In the mammals (VII–X) only two of these bones (the malar and the lacrymal) remain. In the lower forms the eyes are on the sides of the muzzle behind the upper jaw, and they look sideways. In anthropoids and man they are above the upper jaw and are directed forward.

Column C.—Evolution of the jaws. In adult man the upper jaw on each side is composed of two fused bones, the premaxilla (intermaxillary) and the maxilla. The lower jaw on each side is composed of a single bone, the dentary. These bones are present in the lower vertebrates. As we pass from fish to man the maxilla and the dentary become larger and the dentary at Stage VII effects a new contact (the temporo-mandibular joint) with the skull. In the anthropoid and man the jaws become deepened and shortened in front beneath the eyes.

Column D.—Evolution of the temporo-mandibular bones. In the fish (I) the cheek plates cover the jaw muscles and are continuous below with the infra-dentary bones. In the reptiles this series is represented especially by the squamosal and angular bones. In mammals (VII-X) only the squamosal remains visible, to form the squamous portion of the temporal bone.

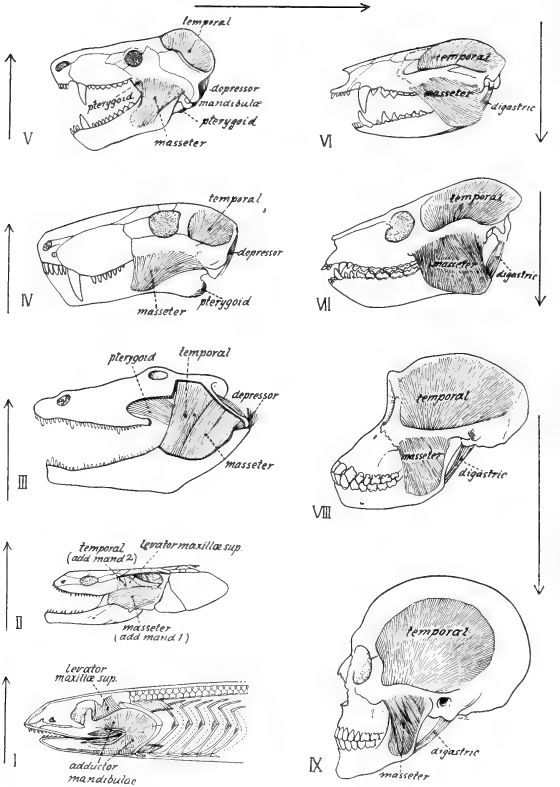


Fig. 25. Evolution of the jaw muscles.

I. Shark (*Chlamydoselachus*).
II. Lobe-finned ganoid (*Polypterus*).
III. Primitive amphibian (*Eryops*).
IV. Primitive mammal-like reptile (*Scymnognathus*).
V. Advanced mammal-like reptile (*Cynognathus*).
VI. Opossum.
VII. Primitive primate (*Notharctus.*)
VIII. Chimpanzee.
IX. Modern Man.

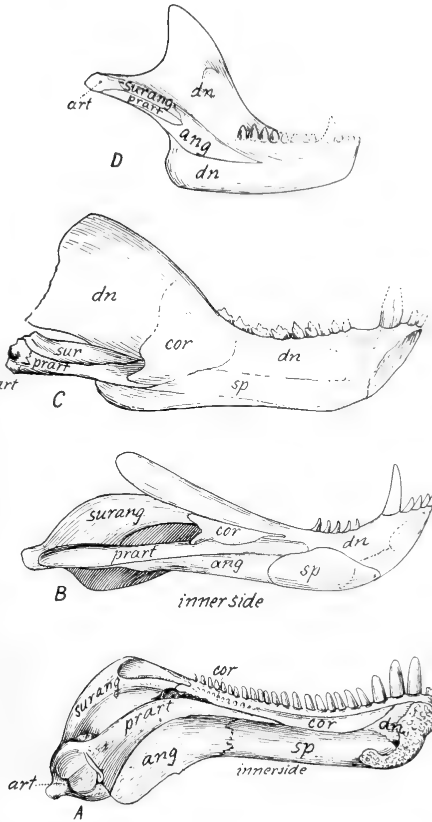
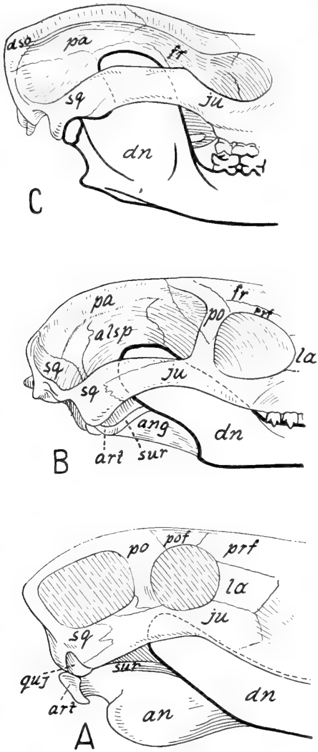


Fig. 26. Progressive increase of the dentary (*dn*) and reduction of the elements behind the dentary, leading to the mammalian jaw, which has formed a new articulation with the skull (see Fig. 27).

Inner side of left half of mandible.

A. Primitive theromorph reptile, *Dimetrodon*. After Williston.
B. Primitive gorgonopsian, *Cynarioides*. After Broom.
C. Progressive cynodont, *Cynognathus*. Partly after Watson.
D. Ictidosaurian. After Broom.



Courtesy G. P. Putnam's Sons

Fig. 27. Progressive upgrowth (A, B) of the ascending branch of the dentary bone of the lower jaw, which eventually, in the early mammals (C), effected a contact with the skull, thus forming a new joint. Meanwhile the old joint (at the back of A) dwindled away.

A. Primitive mammal-like reptile; B. Advanced mammal-like reptile; C. Primitive mammal.

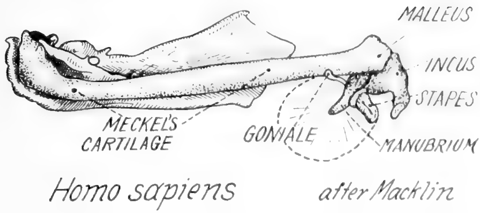


Fig. 28. Auditory ossicles of foetal stage formed from jaw elements behind the dentary.

Evolution of the Auditory Ossicles [Case 25]. The auditory ossicles of man, like those of mammals, are derived in the course of embryonic development from parts of the "visceral arches" corresponding to the cartilaginous jaws, hyoid arch and branchial arches of the fish. Thus in the human embryo the future incus (anvil) is represented by a little cartilage that has the precise position and spatial relations of the quadrate bone of the lower vertebrates; the malleus (hammer) is a part of the Meckel's cartilage, or core of the lower jaw; while the stapes represents the upper part of the hyoid arch (Fig. 28). This interpretation of the origin of the mammalian ossicles was first put forward by the embryologist C. Reichert in 1837, but it has been greatly extended and confirmed by modern investigators, especially E. Gaupp of Fribourg.

In the series of fossil vertebrates from fish to man, the cynodonts, or pro-mammals of the Triassic age of South Africa, show a critical stage in the evolution of the auditory ossicles, immediately preceding the mammalian condition (Fig. 26 C, D). The dentary bone of the lower jaw has increased in size and the bones behind it have become much smaller. As in modern reptiles, the tympanum, or ear-drum, was very probably connected by ligaments with the back part of the lower jaw. Hence in these animals the articular, quadrate and columella auris had already begun to function respectively as the malleus, incus and stapes.

This amazing but now fully documented transformation of jaw elements into auditory ossicles affords an excellent example of the principle of the "change of function."

For the relations of the auditory ossicles to other parts of the organ of hearing, see Fig. 33 and page 64.

Evolution of Molar Teeth. It has been shown by palæontologists that the more complex forms of the crowns of the molar teeth of mammals have evolved from a simple triangular or tritubercular pattern. This was the most important part of the "Cope-Osborn Theory of Trituberculy," developed by the American palæontologists Edward D. Cope and Henry Fairfield Osborn between 1883 and 1907.

The series of enlarged models of teeth of fossil and living mammals (Fig. 29) represents eight stages of advancement from the Jurassic period to the present time.

The series as a whole shows the transformation of the upper molars from an irregular cutting and piercing triangle to a rounded, four-cusped grinding tooth.

In the lower molars the progress is from small cutting triangles with very small posterior heels to large oval grinders with low conical cusps and a large central basin.

Noteworthy details of this transformation are as follows:

In the second stage (B) the tip of the upper premolars is represented in the molars by a large conical cusp (solid black) called the amphicone. In the later stages the amphicone divides into two cusps (paracone and metacone), which move apart as the hypoconid of the lower molars comes to fit between them.

The "protocone" of Osborn is apparently not the oldest cusp of the upper molars but arises as a swelling or bud on the inner side of the base of the crown.

In the earlier stages the outer part of the crown, called the cingulum, is very large, but after the fourth stage (from the bottom) it disappears, leaving the paracone and metacone on the outer border of the crown.

In the fifth stage a new cusp, the hypocone, grows up, filling the space between the upper molars and changing a triangular into a roundly quadrangular crown.

In the lower molars we observe that in the earlier stages the talonids or heels are small, but finally they become larger than the trigonids (or lower triangles). As this happens, the protocones of the upper teeth enlarge to fit into the expanded talonid basins. The paraconids, or anterointernal cusps of the lower molars, disappear at the fifth stage, while the hypocones of the upper molars become enlarged.

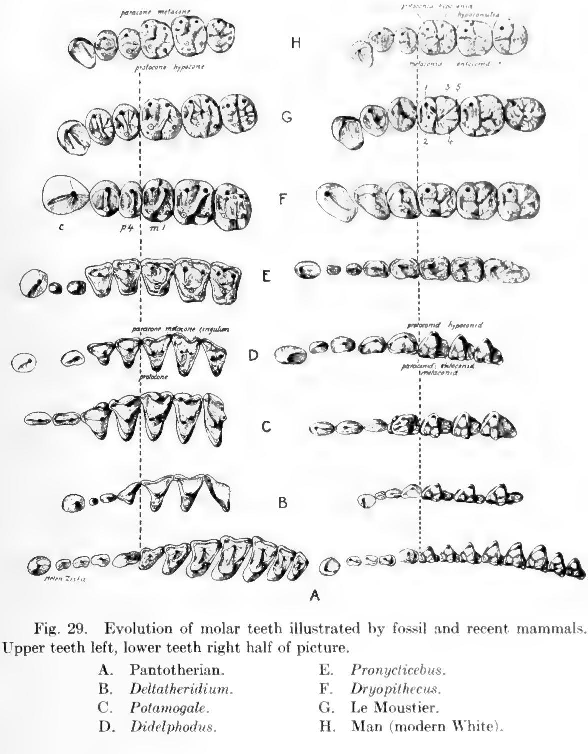


Fig. 29. Evolution of molar teeth illustrated by fossil and recent mammals. Upper teeth left, lower teeth right half of picture.

A.	Pantotherian.	E.	*Pronycticebus.*
B.	*Deltatheridium.*	F.	*Dryopithecus.*
C.	*Potamogale.*	G.	Le Moustier.
D.	*Didelphodus.*	H.	Man (modern White).

THE NERVOUS SYSTEM AND ITS FUNCTIONS

Elements of the Nervous System

[**Case VIIB**]

Man, like other organisms, is a living solar engine, run by the energy of the sunlight that is stored in plant and animal food (See Case I).

This stolen energy may easily drive its user to destruction unless quick adjustments are constantly being made against dangerous forces both inside and outside the body.

The nervous system makes these adjustments possible; it also determines which one of several alternatives shall be followed when competing interests are at stake. In very simple animals a good adjustment is presumably rewarded by a sense of well-being or pleasure, while a bad adjustment gives rise to a sense of pain. In the higher animals the immediate pursuit of pleasure and the avoidance of pain is complicated by memories of the good or bad consequences of past behavior.

This exhibit is intended to show how the simplest elements of the nervous system are built up into the amazing complexities of the brain; similarly, the science of psychology strives to trace an orderly historical sequence from the elementary reactions of an amœba to the most abstruse reasonings of mathematicians.

A few of the myriads of vibrations which constantly rain down upon us are caught by tens of thousands of sense organs, or receptors, scattered almost everywhere on the surface of the body and in its interior. The receptors for smell and taste are able to catch chemical stimuli; the receptors for touch, pressure, hearing, receive mechanical or physical stimuli; the receptors for light, color-waves, heat and cold, are sensitive to radiant energy.

The position of the body in reference to the direction of the force of gravity (balance), as well as the position of the different organs and parts to each other, is indicated by several kinds of "receptor organs" sensitive to pressure and located in the skin, in the tendons of the muscles, in the joints and elsewhere.

When a receptor is excited it starts a current of "negativity" in the ions of the neurons. The discharge of the current at the end of a neuron starts a current in the one above it, and so on by relays along afferent nerves up to the brain; then other currents start in various directions in the cortex of the brain; thence new currents pass down the efferent neurons to the effectors, or motor organs, including muscles around the glands.

The "Sympathetic" (Autonomic) Nervous System. The nervous system as a whole is composed of two main divisions: (1) the cerebro-spinal system, including (A) the brain, (B) the cranial nerves, (C) the spinal cord, (D) the spinal nerves; (2) the autonomic nervous system, including a vast network of fibers ending in the unstriated muscular coats of the blood-vessels and in the mucous membranes and other parts of the glands and other internal organs.

The autonomic system comprises two main divisions, sympathetic and para-sympathetic, which oppose each other in regulating the action of the ductless glands, viscera, blood-vessels, etc.

The larger branches of the sympathetic nervous system unite to form a series of ganglia on each side of the spinal cord. Each of these ganglia is connected by delicate branches with the corresponding spinal nerve of the cerebro-spinal system. The ganglia of the sympathetic system arise in the mammalian, human and other embryos from the lateral margins of the neural crests. Hence the sympathetic ganglia are really only differentiated portions of the central nervous system.

Spinal Nerves. In such a primitive vertebrate as a shark the muscular part of the body is divided into a series of segments called somites, which surround the non-segmental digestive tract and spinal cord. Each somite contains one vertebra and one pair of spinal nerves.

Each spinal nerve issues by two roots, dorsal and ventral, from the spinal cord between the neural arches of the vertebræ. The motor (ventral) root is so called because it motivates the muscles of the trunk and limbs. The dorsal and ventral roots unite to form a common trunk. This subdivides into a dorsal and ventral primary division, both carrying motor and sensory nerve fibers. Smaller branches finally supply the sense organs in the skin and the skeletal muscles beneath. This arrangement, which makes possible the spinal reflex, is found in all vertebrates from fish to man. In certain vertebrates, especially reptiles, those spinal reflexes that cause wriggling of the body may continue long after the cord has been severed; but in the mammals these reflexes are more or less under the control of nerve centers in the brain-stem.

Reflex Action. In the "knee-jerk reflex" a slight tap just below the knee stimulates the sense organs of pressure in the tendon of the extensor muscle of the leg. Nervous impulses then travel up the afferent nerves through the posterior or sensory root of the spinal nerves into the spinal cord itself; there the afferent currents pass into fine terminal nerve branches which come very near to, but do not actually cross over into, equally fine terminal branches of the descend-

ing or efferent nerves. Somehow the currents in the afferent branches induce corresponding currents in the efferent branches and these travel out through the anterior or motor root down the efferent nerves to the nerve endings, or end-plates, which are fastened to the sides of the muscle fibres. The discharge in these end-plates initiates the contraction of the extensor muscles on the thigh and the lower leg suddenly kicks forward.

This reflex is practically automatic or involuntary, since the reaction between afferent and efferent impulses takes place in the spinal cord with little or no control from the brain.

Cranial Nerves. The "cranial nerves" are paired nerves that issue from the brain and brain-stem in front of the spinal cord. In all vertebrates from fish to man the cranial nerves are arranged in the following traditional sequence:

Nerve pair	Name	Function
I	Olfactory	Nerves of smell
II	Optic	Nerves of sight
III	Oculomotor	Motor nerves to four out of the six muscles of the eye-balls, as well as the ciliary muscles and muscles of the iris in the interior of the eyes
IV	Pathetic or Trochlear	Motor nerves to superior oblique muscle of eye-balls
V	Trigeminal	
V 1	Ophthalmic branch	Sensory nerves to front of head
V 2	Superior maxillary branch	Sensory nerves to face, palate
V 3	Mandibular branch	Motor nerves to jaw muscles; Sensory nerves to teeth, anterior part of tongue
VI	Abducent	Motor nerves to external rectus muscle of eye-balls
VII	Facial	In fish the sensory branches go mostly to the lateral line organs of the face, the motor branches to the muscles of the neck and gill covers
VIII	Acoustic	Sensory nerves of the inner ear or labyrinth
IX	Glosso-pharyngeal	Sensory branches to taste organs of the tongue and pharynx Mixed branches to second gill cleft
X	Pneumogastric or Vagus	Sensory and motor branches to lateral line, branchial arches, lungs, heart, stomach
XI	Spinal accessory	Motor nerves to branchial arches and muscles of the neck
XII	Hypoglossal	Motor nerves to muscles of tongue

In mammals nerve XI is derived from part of X, while XII represents one or more of the spinal nerves of lower vertebrates.

In mammals, including man, the general arrangement and distribution of the cranial nerves is substantially the same as in fish but with these important exceptions:

(1) With the abandonment of aquatic life the lateral line system of sense organs has disappeared from the head and neck, and with it the corresponding branches of the seventh cranial nerve.

(2) The gill covers, their sensory organs and special nerves have also disappeared but some of the muscles of the hyoid arch are still present and function in operating the larynx, or voice mechanism.

(3) In the ancestors of the mammals some of the superficial muscles of the neck grew forward under the skin to form the facial or mimetic muscles, carrying with them branches of the seventh or facial nerve (see Case VI).

Modern anatomists have discovered that there are several additional pairs of cranial nerves, not noticed by the older anatomists.

THE BRAIN

[Case VIII]

SENSATION

PALAEOKINESIS: ACTION CONTROLLED BY THE SENSES. The main divisions of the shark's brain correspond to the organs for smelling, seeing, balancing, touching and tasting. The brain is surrounded by these organs and consists of bundles of nerves that come from them and from the spinal cord, the latter being the main mass of nerves from the internal organs, muscles and skin of the body.

The reactions of the shark to its environment are controlled directly by its senses. Thus pleasure and pain produce opposite and immediate direct response. This type of reaction is called palæokinesis (ancient action) in contrast with the more deliberate response of the highest animals, which is more or less controlled by ideas (neokinesis) (Figs. 30 and 31).

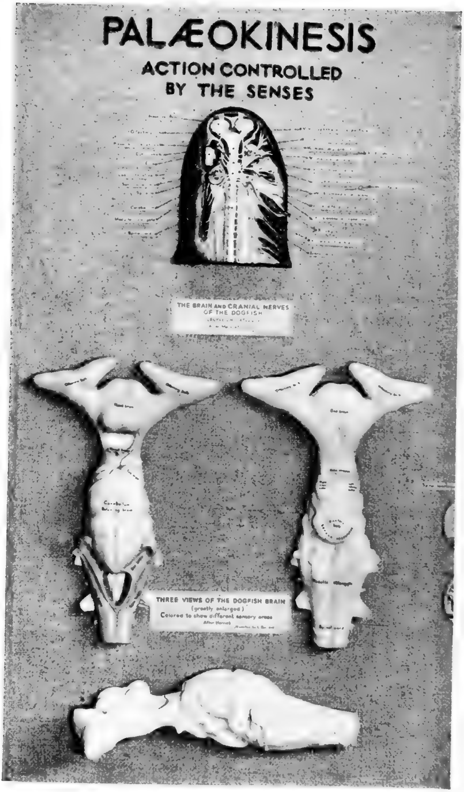


Fig. 30. In the shark the nose brain, ear brain and cerebellum dominate the midbrain, which in the fish is the main center of control.

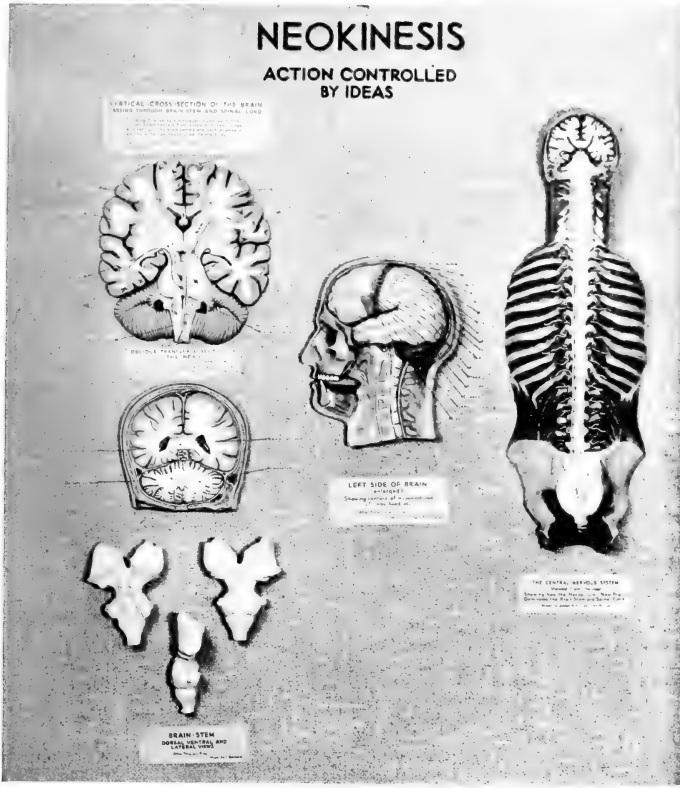


Fig. 31. In man the center of control has moved upward into the cerebral cortex, which dominates all the parts below it.

Touch, Pressure, Pain, Heat, Cold, etc. In the skin of vertebrate animals we find several kinds of sense organs which may be called CONTACT receptors, in contrast with DISTANCE receptors, including the eye and ear. The contact receptors give rise to the senses of touch, pressure, pain, heat, cold and perhaps other sensations. They are widely distributed over the skin and are supplied by the cutaneous nerves. The latter lead back to the dorsal roots of the spinal nerves and thence up the spinal cord to the medulla oblongata of the brainstem, where the centers for these senses are located.

The muscles, tendons and joints of the body are also supplied with end organs that are sensitive to pressure. Movements of one part on another, or even the arrest of movements as in fixed postures, stimulate the end organs in the tendons and joints and thus inform the brain of the position and state of tension of each part. These receptors are innervated by branches of the spinal nerves.

Other receptors, called enteroceptors, located in the viscera and in the muscular parts of the heart and blood-vessels, appear to be sensitive to the pressure of gases and liquids, while still other receptors in the intestines may be sensitive to chemical stimuli of the body fluids. The viscera are innervated by the vagus nerve (parasympathetic) and sympathetic systems.

Smell. The olfactory receptors, or organs for the sense of smell, are classed as chemo-receptors because they are stimulated by certain chemical substances dissolved in olfactory mucous, a watery solvent. These solutions affect the sensory hairs of the olfactory epithelium, perhaps by reacting with the solutions contained therein.

There is evidence that the sense of smell was very highly developed in the oldest types of fishes and that there has been a marked reduction of this power in the nearer ancestors of man. In a certain large shark, according to Haldane and Huxley, the olfactory epithelium (which is greatly infolded and packed into the olfactory capsules) had an immense area, estimated at twenty-four square feet. In a dog, which like most ordinary mammals has a relatively keen sense of smell, the olfactory epithelium if unfolded would cover about ten or more square inches. In man, although the nasal cavity is lined with mucous membrane, only a very small area (about one-fourth of a square inch) is supplied with the branches of the olfactory nerve, all the rest being insensitive to smell.

Similarly, those parts of the brain which relate to the sense of smell have become much reduced in man and his nearest relatives, the anthropoid apes.

Taste. "Taste buds," or receptors for taste stimuli, in the human adult are located in several places, chiefly on the tongue, epiglottis and soft palate.

The four principal tastes are differently distributed on the surface of the tongue: "sour" is best noted on the sides of the tongue; "saline" on the sides and tip; "sweet" at the tip; and "bitter" at the base.

Three, or possibly four, of the paired cranial nerves include gustatory fibres. The chorda tympani branch of the seventh nerve separates from the lingual nerve (a branch of the fifth) and sends gustatory fibres to the anterior two-thirds of the tongue. The glosso-pharyngeal, or ninth, supplies the posterior third of the tongue, including the foliate and vallate papillæ; while branches of the tenth (vagus) are distributed to the larynx, the epiglottis and to a small area at the most posterior part of the tongue itself. In human fetuses and babes taste buds are more widely distributed than in the adult.

In the brain afferent nerve fibres from the taste buds discharge their currents into "nuclei," or centers in the medulla oblongata. Then by relays the gustatory messages are conveyed to the brain. The kind of response of the brain as a whole to these stimuli will depend in part upon the data supplied by the various centers of memory and association (See Fig. 31, Neokinesis).

Sight. The "basic patent," or most fundamental feature of the eye, is the battery of light-cells (rods and cones) in the retina, whereby the energy of the light waves is converted into visual nerve impulses which travel along the optic nerve to the brain.

The rods of the retina contain "rhodopsin," or visual purple, and it is possible that the decomposition of visual purple under the influence of light causes excitation of the rods. The cones have no visual purple but probably do contain some other photo-sensitive compound.

The efficiency of the light-cells is immensely increased by the fact that the eye as a whole is a natural camera, whose chief parts are as follows: (1) a dark chamber, in which the light is admitted only through a small circular aperture called the pupil; (2) a sensitive plate called the retina; (3) a lens for focussing the image; (4) muscles of accommodation for altering the curvature and focal length of the lens; (5) a contractile iris for regulating the amount of light admitted to the chamber.

But the eye is a living camera, all of whose parts have to be fed with materials for maintenance and growth. Hence it possesses a great many features not found in an ordinary camera. The retina, for example, is crowded with nutrient blood-vessels, which supply the many layers of rods and cones.

A small circular spot called the fovea, which lies within the macula on the back of each retina, is far more sensitive to light than is the surrounding area. These sensitive spots enable the two eyes to converge on a single small object. This convergence is effected by the coöperation of the two sets of eye muscles. Each eye is moved by six muscles, which together form a cone surrounding the optic nerve. Focussing is done by muscles attached to the lens.

The cornea, or transparent front window of the eye, is continuous with the sclerotic coat. Specks of dirt, sand, etc., are washed off by tears from the lacrymal gland in the outer corner of the eye.

In primitive vertebrates the optic lobes on the upper part of the midbrain were the chief receiving centers for visual stimuli, but as the neopallium, or higher brain, became larger and more complex (Fig. 32), the "optic radiation" on the occipital surface of the cerebrum became increasingly important; in the mammals the old optic lobes serve as reflex centers for the eye muscles.

In the anthropoids and man nerve fibers from each eye cross over to the opposite half of the brain; others go directly to the same side of the brain. This makes possible complete overlap of the two visual fields, resulting in "stereoscopic vision."

The position of the paired eyes in primitive vertebrates is on the sides of the head but in the mammals there is a tendency for the eyes to be directed forward. Finally in the anthropoid apes and man the eyes look wholly forward and are not only capable of converging on an object but can both follow an object moving in any direction within the combined field of vision (biconjugate movement) [Case 26].

In the vertebrates the eyes arise in the embryo as pockets in the medullary folds of the future brain. The optic stalk and cup then grow outward from the base of the rapidly swelling midbrain. When the optic cup touches the outer layer it gives out a chemical substance that causes the ectoderm to thicken into a lens.

Fig. 32. The Rise of the human brain (Wall Chart 7).

From fish to man the brain increases in complexity and in the size of certain parts, especially the forebrain. In the lower forms the forebrain functions chiefly in connection with the "olfactory bulbs," and smelling nerves. In the mammals the upper part of the forebrain becomes differentiated as the neopallium, or new brain, gradually assumes control and finally becomes greatly convoluted or infolded, largely concealing, especially in the side and top views, the older parts of the brain.

Although the forms whose brains are figured above are all living at the present day and therefore not ancestral one to the other, their brains represent a progressive series from lower to higher types.

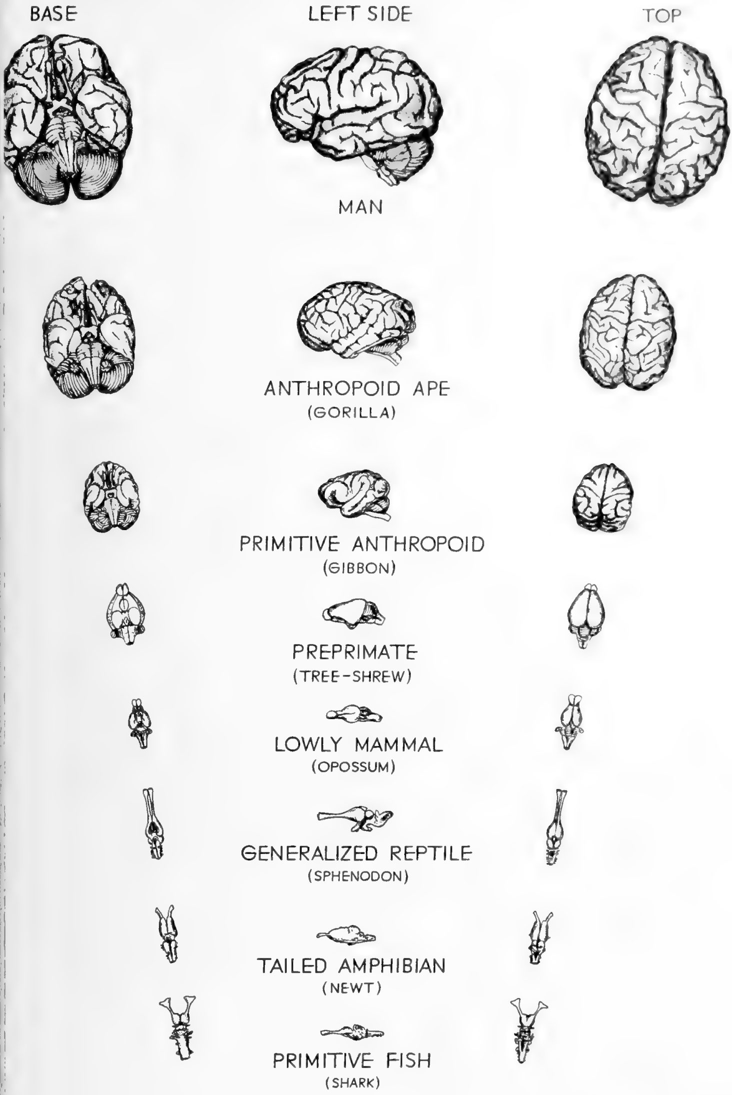

BASE
LEFT SIDE
TOP
MAN
ANTHROPOID APE
(GORILLA)
PRIMITIVE ANTHROPOID
(GIBBON)
PREPRIMATE
(TREE-SHREW)
LOWLY MAMMAL
(OPOSSUM)
GENERALIZED REPTILE
(SPHENODON)
TAILED AMPHIBIAN
(NEWT)
PRIMITIVE FISH
(SHARK)

Fig. 32.

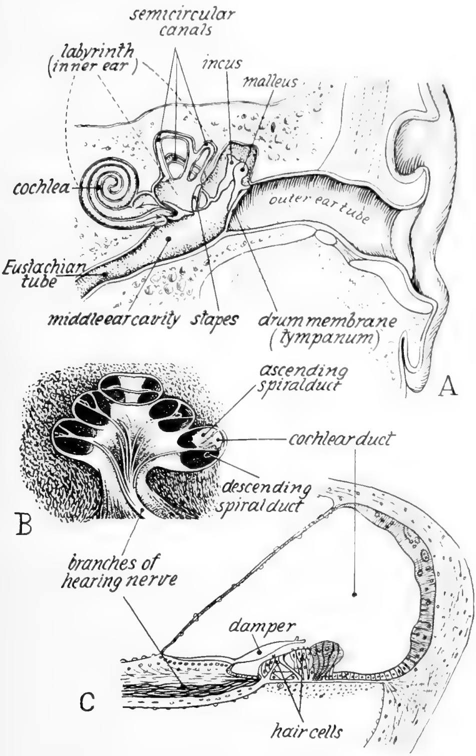
The general structure of the eye throughout the vertebrates is remarkably constant, the chief differences between the eyes of fishes and those of land-living vertebrates being that in the former the lens is more convex and its focal distance shorter.

Hearing. The organ of hearing (Fig. 33) is classed among the mechanical receptors because it responds to mechanical stimuli, which in this case are the pulsations of sound waves in the air against the tympanum, or ear-drum. The outer ear (concha) and its tube (the external auditory meatus) serve merely to collect and conduct the sound waves to the tightly stretched ear-drum. The latter is located at the entrance to the tympanic cavity, which in turn leads to the Eustachian tube (tuba auditiva), connecting with the throat. The degree of tension of the ear-drum is regulated by the tensor tympani muscle, the tendon of which is fastened into the handle of the hammer, or malleus. The latter is the outermost of a chain of three little bones (ossicula auditus) that transmit vibrations of the ear-drum to the membrane of the oval window (fenestra ovalis) of the inner ear (see p. 51).

The three little bones are geared together in such a way that the relatively wide but weak oscillations of the ear-drum are transformed into much shorter but more powerful thrusts of the foot-plate of the stirrup, or stapes. The vibrations of the latter start waves in the liquid that fills the snail-shell, or cochlea; this in turn contains the organ of Corti, or true organ of hearing.

The waves of pressure travel up the liquid in the coils of the cochlea in the upper division thereof (scala vestibuli), passing over the sensory hairs of the acoustic epithelium and thus initiating nerve currents which pass through the afferent acoustic nerves to their centers in the brainstem. Numerous relays pass thence to and from the temporal lobe and other parts of the brain. After reaching the top of the cochlea the pressure waves come down the lower division of the coil (scala tympani) and appear to escape through the vibrations of the membrane covering the round window (fenestra rotunda) at the lower end of the cochlea. The cochlea seems to analyze sound waves by some mechanism for sympathetic vibrations. Since the sensory cells of the organ of Corti are arranged in a spirally-wound series, it is possible that they are sensitive, like the wires of a piano, to different wave lengths. Other structures in the ear, for example the basilar membrane, have been considered as the significant part in the resonating apparatus.

The semicircular canals are sometimes called the chief organs of balance, or equilibration, because they supply sensory stimuli that vary



Courtesy G. P. Putnam's Sons

Fig. 33. The Human Organ of Hearing and Balance.

A. Transverse section.

B. Diagram section of the cochlea, showing the ascending and descending spiral duct and the cochlear duct containing the organ of Corti, or true organ of hearing.

C. Greatly enlarged view of the cochlear duct, showing the organ of Corti with its damper, hair cells and hearing nerves.

(A and C, after Cunningham.)

according to the inclination of the head toward the pull of the earth's gravitation. There are three semicircular canals, the anterior vertical, posterior vertical, and external or horizontal canals, arranged at right angles to each other in the three planes of space. They are supposed to act like spirit-levels. The canals are filled with liquid and lined with sensory hair-cells, which are connected with nerve fibres from the upper division of the eighth cranial nerve. The chief centers of balance are in the medulla and cerebellum. The absence of direct connections with the cortex of the cerebrum indicates that the mechanism for equilibration is largely reflex.

Semicircular canals were present in the very oldest known fossil vertebrates and are remarkably constant in their general arrangement in the existing vertebrates from fish to man.

The cochlea, or organ of hearing, on the other hand, first appears in the higher reptiles and becomes fully developed only in the highest vertebrates, which are the birds and mammals.

The acoustic, or eighth pair of cranial nerves, is in series with the vagus, or tenth, and the entire labyrinth, including its nerves, is regarded as a highly differentiated and specialized portion of the lateral line organ system of fishes.

The entire labyrinth, or inner ear, arises in the early embryo as a pocket of ciliated epithelium, an infolding of ectoderm. In later stages this pocket becomes divided: the dorsal half gives rise to the canals and the utriculus, the ventral, to the cochlea.

Response

Memory. The first "basic patent" for memory is the fact that when a nerve current comes up to the brain from a sense organ, it induces another discharge or series of discharges, in the cortex of the brain itself, and that these discharges appear to leave some physical traces behind them, analogous perhaps to stains. To use a crude analogy, the more intense and wide-spread the sensory discharges, the deeper the stains will be and the longer time it will take to wash them out. In this connection it is an interesting fact that there is a close resemblance between the "curve of forgetting" and the curve of times necessary for washing out dye-stains in certain tissues.

The second physical basis of memory is the fact that every "center" in the brain is connected with many other centers by "association fibres." Adjacent sensory and motor areas on the surface of the cortex are connected by short association fibres, while long association

fibres connect the occipital, parietal and temporal lobes with each other and with the frontal lobe, toward which the association fibres converge. The millions of "afferent" fibres come up to the cortex from the sense organs, passing through such crowded pathways as the thalamus, the lenticulate nucleus and the corona radiata, and the currents that they discharge leave their traces in many parts of the brain.

Memory, both conscious and unconscious, is the first basis of the "conditioned reflex," and eventually of habit-forming and the learning process. "The burnt child fears the fire," and even a pike will soon learn not to strike his nose against the glass in an aquarium.

Memory is of the highest value in all vertebrates, including man, because it enables its possessor to profit by experience, to "see things coming" and to make effective adjustments before the storm breaks or before a given course of action leads to disaster.

Speech. While all the senses such as touch, taste, smell, sight and hearing are constantly pouring their stimuli into the brain, the brain also responds in various ways, as by bodily movements, by an increased glandular secretion, or perhaps by arrested movement with heightened internal pressure. Finally, in the case of man, response may issue in speech or in its shorthand record which is called thinking. Spoken words, considered as purely physical events, are merely noises caused by puffs of air rushing across the vocal cords of the larynx and variously checked or otherwise modified by the action of the larynx, tongue, palate, teeth and lips.

The larynx represents a highly specialized derivative of the complex gill-arch apparatus of the fish. The several bones of the larynx may be followed backward along the descending scale of living vertebrates to the corresponding parts in the branchial skeleton of the fish, and this is true of each of the muscles of the larynx. The skeleton of the tongue is derived from parts of the hyoid arch and of the median bars of the branchial arches. The muscles of the tongue are innervated by branches of the hypoglossal, the twelfth cranial nerve, while those of the larynx are supplied by the tenth. It is noteworthy that these same cranial nerves, the tenth and the twelfth, also supply the tongue and branchial muscles of lower vertebrates.

Thought. In neurological terms, thinking may be defined as a more or less organized series of discharges, in the surface layers of the brain, of the various "association systems," acting in unison with each other; reacting to present sensory patterns but always conditioned by emotional stresses left over from past sensory, motor and associational discharges.

Due to these diversely conditioned reactions established by past experience and habit, similar sensory-motor patterns do not always induce the same associational responses. On the other hand, a characteristic part of a pattern often induces the same response as does the whole pattern.

Thinking involves a process which may be compared with the projection of two streams of pictures upon the same screen. The first stream includes such reflections of the outer world as are transmitted by the sense organs and their nerves; the second stream is composed of the blurred, distorted images furnished by memory. The "screen" is found in the projection areas of the "association systems," especially those on the frontal lobes of the brain.

Thinking may be defined as the process of matching new sensory patterns with the memories of past ones and of responding in different ways to identities and differences between these patterns. Thinking, in this sense, apparently goes on in all the higher animals, including man, and is developed with the increase in size and complexity of the prefrontal projection centers.

In verbalized thinking, which is peculiar to man, complex sensory patterns are represented by relatively simple auditory and visual verbal symbols. These symbols, through a series of historical events, now have a more or less uniform significance to all normal persons speaking the same language. Hence words are the currency of thought.

In scientific thinking there is an emotional stress or passion to analyze sensory patterns, to make close comparisons and measurements, to distinguish between symbols of identical wholes and symbols of wholes that are superficially similar but fundamentally distinct, and finally to trace historical and causal sequences in all fields open to human investigation.

Neokinesis: action controlled by ideas. In the lower vertebrates, as typified by the shark, response to sensory stimuli is largely direct. A "good" smell in the water causes the animal to turn toward the sources of the pleasant stimulus, to swim toward it and to devour it. Memory of past results plays comparatively little part in modifying behavior. In higher animals, on the other hand, only "reflex" acts are free from the restraining or encouraging influence of memory. Perhaps all conscious acts are "conditioned" by memories or ideas, which are generated or conveyed by the complex association tracts of the neopallium, or higher brain (Fig. 31).

The peculiarly human power of speech has made it possible for ideas to be handed down from generation to generation and to be built up into systems of social control that tend either to encourage or to inhibit particular responses to sensory stimuli.

EPITOME

The Rising Scale of Life

The existence of a rising scale of life ("l'échelle des êtres") leading from the lowest one-celled organisms to man was suspected by some of the ancient Greeks and demonstrated by the naturalists of the eighteenth and nineteenth centuries, especially Lamarck, Darwin and Haeckel. It remained for the palæontologists of the nineteenth and twentieth centuries to discover a long series of extinct vertebrates from successive ages of the earth, forms which carry forward the story of the origin and rise of prehuman and human characteristics in an orderly and well established sequence (Fig. 4).

The earliest known forerunners of the vertebrates were the ostracoderms, or jawless fishes, whose fossil remains are found in rocks of the Ordovician and Silurian periods; the age of the oldest of these fossils is estimated at nearly five hundred millions of years. From this time onward the vertebrates are known from more and more branches. Many of these branches became extinct, but others went on and gave rise to new branches; both old and new branches together form the Tree of Life. The definition and classification of these larger and smaller branches belong in the fields of zoölogy and palæontology; but a practical knowledge of the Tree of Life is a necessary prerequisite for correct appreciation of the fossil record of evolution, from fish to man (Figs. 8, 24, 36).

Nature's "Basic Patents"

When Nature at last works out a new and successful mechanical device in one group of animals and in one part of the world, she bequeaths this treasure to their diversified descendants in many lands. The "one-piece jaw" arose among the earliest mammals of the Triassic age (Figs. 26, 27) and was transmitted with innumerable modifications in detail to countless millions of later mammals, including man.

Another example of an important "basic patent" is the neopallium, or higher brain, which likewise arose in the earliest mammals as a super-control system (see Fig. 32); in the higher mammals it has become the organ of intelligence.

Resemblance between relatives is normally due to inheritance from one or more common ancestors. Therefore when two animals of different species resemble each other in possessing numerous "basic patents" in common, it is inferred that they are more or less closely related by descent from a common ancestor.

Man's Habitus and Heritage

The later additions to an animal's capital stock of "basic patents" usually fit him for some special way of locomotion, such as climbing, running, walking, swimming, flying, or for some particular range of food habits. The totality of these newer adaptations is called the HABITUS. The older adaptations, which he has inherited from very distant ancestors, are grouped together as his ANATOMICAL HERITAGE.

Man's HABITUS includes his fully erect posture and all that this implies in the unique details of his backbone, pelvis and feet. His habitus also includes his enormous brain, his diminished jaws and his power of speech. As to his ANATOMICAL HERITAGE, he shares a very great number of deep-seated anatomical and physiological characters with the anthropoid apes, especially the gorilla and the chimpanzee.

The Principle of Changing Function and Structure

Many of the most striking of man's characteristics have arisen by "descent with modification" and through "change of function and structure."

Thus man's skilful hands, with which he has built up his civilizations, represents the modified fore feet of remote quadrupedal ancestors (Fig. 8). His feet, which are now so well adapted for supporting the body in an upright posture, have been derived by "descent with modification" and through "change of function" from grasping organs not unlike those of the gorilla (Figs. 17, 18).

During such changes in function there are marked changes in the relative sizes of certain parts. Thus in the immediate ancestors of man the thumb (Fig. 16) became longer, the hand wider, the outer toes (Fig. 17) shorter, the femur (Fig. 8, I, J) longer, while opposite changes took place in the orang-utan, which became highly specialized for arboreal life.

Man's much admired face is molded upon the fish-trap of a creature that was no higher than a shark; his voice, which he now broadcasts over the world, issues from an apparatus originally made out of the gill-bars of a fish; his very brain, by means of which he has discovered space-time and plumbed the depth of the atom, began as a simple automatic mechanism for directing his motor and digestive apparatus toward his next meal.

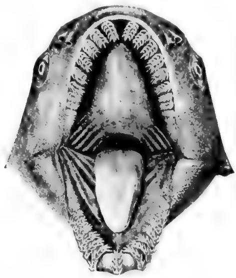


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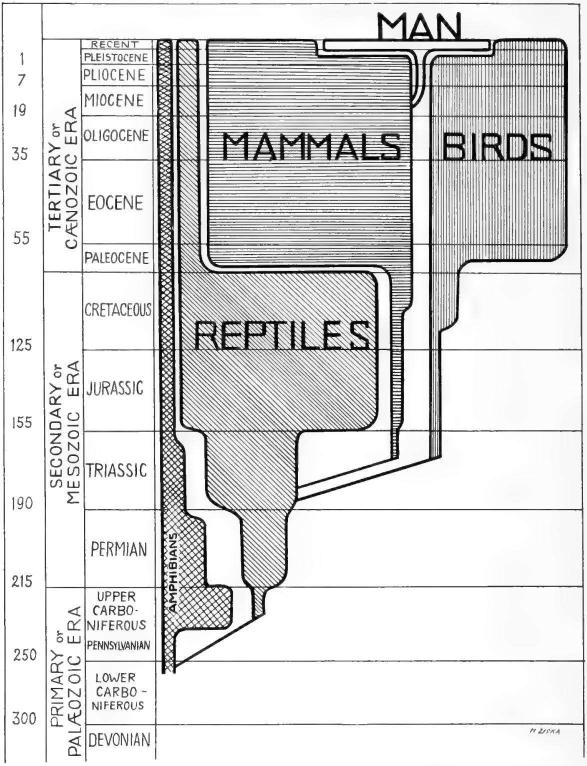
Fig. 35. Man among the Primates (Wall Chart 6).



Courtesy G. P. Putnam's Sons.

Fig. 36. Man's Emergence in Geologic Time.

Numerals at left stand for millions of years since beginning of period, according to rate of "radium emanation" from uranium minerals, based on Barrell's estimates.

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THE NETSUKE OF JAPAN

By HERBERT P. WHITLOCK

Curator of Minerals and Gems, American Museum

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THE AMERICAN MUSEUM OF NATURAL HISTORY

NEW YORK, 1935

The Netsuke of Japan

An account of certain miniature Japanese carvings featuring the mythical stories they tell

By Herbert P. Whitlock

Curator, Department of Minerals and Gems, American Museum

In Japan, where the art of carving both beautifully and delicately in ivory and wood has been carried to such extraordinary perfection, a particular type of carving is unique. The Japanese costume is devoid of pockets, with the result that each person usually carries a handsome bag or detached "pocket" which he attaches to his girdle by means of a "netsuke." This decorative piece, usually of ivory or of wood, is almost invariably a little work of art, and the specimens that illustrate the following article are from the Drummond Collection which recently has been put on display at the American Museum. The word is not pronounced as it is spelled. An approximation of the Japanese pronunciation might be written phonetically as follows: Netski.

—The Editors.

THE Japanese carver in ivory practices an art which is in many respects essentially different from that of his brother craftsman, the Chinese lapidary who works in the harder mediums. His is a handicraft allied in material and technique with that of the wood carver, and, indeed, he often resorts to wood and handles it with the same facility with which he uses ivory.

Unlike the Chinese carver of jade, whose tools are few and simple, the Japanese ivory carver produces his small, realistic works of art with the aid of a multitude of knives, burins, gravers, chisels, drills, files, and saws. A full set of these implements contains upward of fifty pieces, including right-handed and left-handed burins, whose purpose would be obvious to a golfer who uses a left-handed club when the golf ball lies close to the right side of an obstacle, such as a tree root.

Such an array of carving paraphernalia has rendered possible a perfection in the representation of detail which in many cases is little short of microscopic. So meticulous indeed is the work of the Japanese ivory carver, that it often includes a completeness of rendition undreamed of by an Occidental artist. One of the pieces in the Drummond Collection, for instance, depicts a huddle of twenty mice which not only are reproduced to the last hair on the exposed or upper side, but whose feet and claws, not to mention the articulations of the tails, also are faithfully shown on the *under* side, which is usually hidden from view.

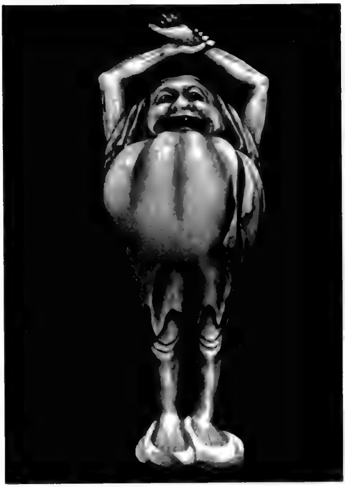
Ingenuity as well as skill is shown by these clever craftsmen, as when they represent a monkey that is capable of running in and out of a hollow log, or an ivory toy representing a street actor that is actually capable of changing his masks by means of the flick of one's finger.

Much of the finest ivory carving in miniature pieces takes the form of netsuke, the buttons or bobs that terminate the cords to which the various girdle appendages are attached, and prevent these cords, when passed through the girdle, from slipping out again. These netsuke, although varying somewhat in size, are, from the nature of their use, small and compact, and are of almost infinite variety in design. There is hardly a legend or folk story known to Japanese legendary lore which has not at some time or other inspired the design of one or more of these clever little carvings. They are dramatic, they are philosophic, and very often they are highly humorous,

[*Reprinted from* Natural History
Vol. XXXV, No. 2, 1935, pp. 121–131]

Skulls are very popular subjects for netsuke among Japanese ivory carvers. The decidedly macabre sentiment which attaches to a medicine box (inro), such a forceful reminder of mortality, is thoroughly consistent with an art that emphasizes the grotesque and the abnormal

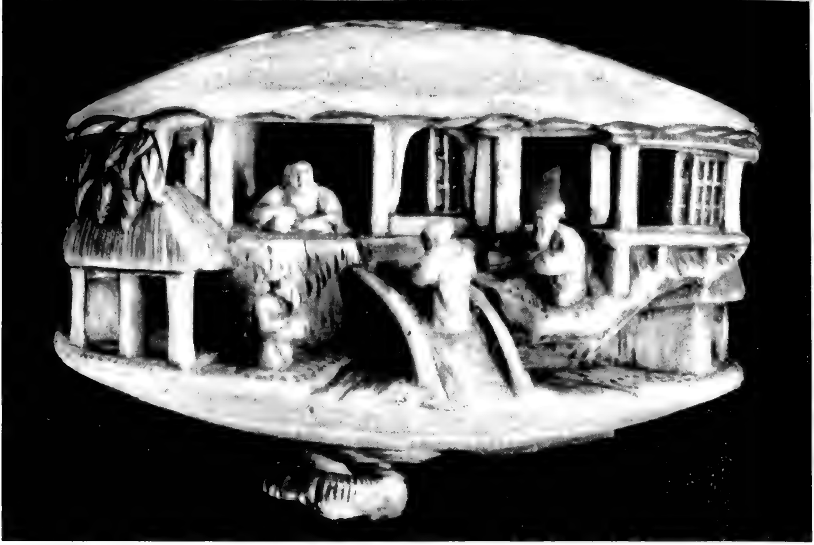
The legless Daruma is a favorite toy among Japanese young people, and is often reproduced as a snow man by Japanese boys. The little netsuke above does not, however, depict such a snow man, but a toy Daruma of heroic size made of papier-mâché



The odd little figure of Daruma is one very often met with among ivory netsuke. Daruma was a sage who, according to tradition, introduced the Zen sect of Buddhism into China. It is said that he remained seated, immovable, absorbed in meditation, for a period of nine years, at the end of which time his legs had "rotted away." He is usually represented in the act of stretching his arms at the conclusion of his long meditation, with his body enveloped in a garment like a bag

Among the many legends to be found in Japanese folklore is one relating to the "foreigners," strange races of people which like Othello's "men whose heads do grow beneath their shoulders" have some singular physical abnormality. By far the most famous of these and the ones most often represented in ivory and wood carvings are Ashinaga and Tanaga. Ashinaga has tremendously long legs and carries on his back Tanaga, whose enormously long arms reach down into the water, when Ashinaga wades out with him in order that they may gather the sea food upon which this cooperative pair lives

The fantastic figure above, executed in wood, represents one of the attendants of Riujin, The Dragon King of the Sea. He wears upon his head a sea dragon, and holds in his hands the fabulous jewel that controls the tides



The Palace of Riujin is shown in this ivory netsuke as being entirely included between the shells of a clam. Another conception makes it a sort of "cloud castle" that materializes from the "breath of a clam"

This ivory netsuke depicts the grotesque figure of Kosensei the Gama Sennin, or the Sage with the Toad. He is always represented with a toad crawling over his person. Sometimes this is represented as the mystic three-legged toad, but oftener it has its full complement of legs

Upon the broad surface of this ivory lotus leaf a priest and an oni, the Japanese word for devil, are engaged in a match of udeoshi — arm wrestling. The identity of the oni is very apparent because, besides having rudimentary horns, he has only three fingers on each hand, and three toes on each foot. We are almost led to wonder if the priest really knows with whom he is contending

A Japanese street actor is called Shishimai, and plies his trade about New Year festival-time much as does a London "Punch-and-Judy-Show" man. The little ivory carving below is in reality a toy representing Shishimai, and is quite as capable of changing its mask as is the actor himself. A clever little wheel inside the figure revolves to a flick of the finger so as to show successively five entirely different masks. The illustrations show two of these

Like the Chinese, the Japanese are fond of depicting fabulous animals. One of the most richly variant of these is the Kirin, derived from the Chinese K'ilin or unicorn. The illustration at the left shows a standing Kirin executed in light-colored wood. This variety of unicorn has two horns instead of one, and seems to be covered with scales

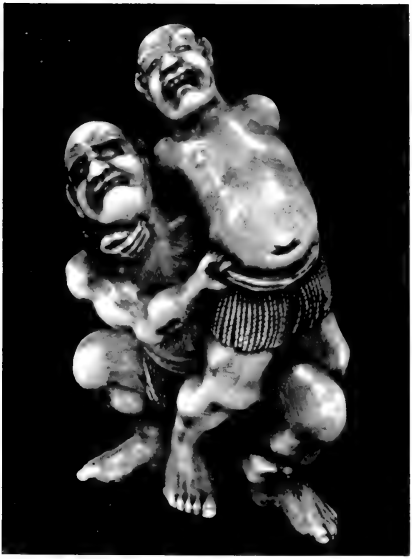
Many of the dances, of which countless numbers are performed in Japan, are religious in character. The subject of the tiny netsuke above is performing Sambaso, the Earthquake Dance, said to have originated early in the Ninth Century to stop the disastrous effect of an earthquake. The mitre-like cap worn by the dancer is decorated with the red disk of the sun

Raiden, the Thunder God, depicted in this little ivory netsuke, has a distinct demonic aspect. The face and rudimentary horns are those of an oni, as are the two claws that decorate each foot, and the three fingers on each hand. He is shown with the drum that he beats to produce thunder

The monkey depicted in this highly humorous netsuke is looking through a magnifying glass at a netsuke carved to represent himself. One could almost imagine the monkey at which he is looking to be looking at a smaller monkey, and so on as far as one cares to carry the illusion

Hotei, the most popular of the seven "Gods of Luck" among Japanese netsuke carvers, is always represented, as in the example below, with a superabundance of flesh, and a very winning smile. Indeed, his generously extensive stomach furnishes a wrestling ground for the two little oni who are entertaining him. He may truly be described as carrying his Madison Square Garden with him

Masks are indispensable adjuncts to the Japanese Nō dances as well as to other theatrical performances. Consequently, they are very often depicted in ivory by the netsuke carvers, either singly or in such groupings as shown in the example below, which presents one or more grotesque faces on whatever side is turned to the observer



Wrestling is as popular in Japan as dancing. This ivory netsuke represents a throw invented by a celebrated wrestler who overcame his opponent when lifted by the loin cloth. This is known as Kawasu's throw

The subject of this beautifully carved ivory netsuke group is none other than Emma, the august Regent of Hell. He is represented as taking a bath while two attendant oni faithfully scrub him. It would be interesting to know whether the liquid is melted sulphur or boiling oil

Shoki, Queller of Demons

Intimately associated with the demonology of Japanese myth is Shoki the Demon Queller. This mythical being, who has furnished the subject of many netsuke, was known in China as early as the Tang dynasty, and was the sworn foe of all the oni or devils. In this netsuke he is depicted as hunting down and capturing several oni in a covered tub

Kijohima, the heroine of this netsuke story, was the daughter of an innkeeper, who fell in love with a holy monk, named Anchin. Upon her advances being met with stern refusal, the love of Kijohima turned to passionate hate, and she summoned to her aid the infernal deities. She pursued Anchin into the temple, where he took refuge under the great bell, which was ten feet in height and enormously heavy. Kijohima, now consumed by a fury of baffled passion, began to undergo a change, her face became a witch's mask, her body became sinuous and dragon-like, and, as she wrapped herself around the great temple bell, flames, emitted from her person, melted it, effectually consuming the unfortunate object of her literally "burning passion"

The subject of this ivory netsuke is Benkei, a hero of the Twelfth Century, famous in Japanese legend. It is said that he was eight feet in height and had the strength of one hundred men. One of his celebrated feats of strength was the carrying away of the temple bell of Miidera. This incident is depicted with great wealth of detail in the carving shown below

because the pursuit of realism in art leads to the grotesque and the abnormal.

It may seem odd to us that the total absence of pockets in Japanese attire has so enriched an art, to say nothing of having produced a devoted band of netsuke collectors. Among these latter were the late Dr. I. Wyman Drummond and his father, James F. Drummond, and it is from Doctor Drummond's collection, now in the Drummond Memorial Hall of the American Museum, that the illustrations for this article are taken. In making a selection from the wealth of material contained in this famous collection, which includes more than 500 carefully selected netsuke, the writer has been at pains to choose those which have a story to tell rather than those whose high artistic worth transcends their mere interest. But, since the ivory artists of Japan never produce an unworthy work, choose as we may, these charming little carvings always appeal to our sense of beauty and fitness.

Even the grotesque ugliness of Tanaga or one of the attendants of Riugin has its enigmatic charm no less than has the captivating serenity of Wang Mu (pictured in "Jade, Amber, and Ivory," NATURAL HISTORY, September, 1934), or the infectious joviality of Hotei. We come to feel that these fabulous worthies have a reality akin to Peter Pan or Long John Silver, and as we all are well aware, that reality constitutes the acme of art.

A question that is often asked and that is somewhat hard to answer is "How old is the oldest ivory netsuke?" One does not hear of any antedating the Eighteenth Century; in fact, it is said that ivory netsuke carving began with the work of Yoshimura Shuzan of Osaka, who lived and worked early in that century. The Eighteenth Century ivory netsuke, however, supplanted similar work in wood, which latter dated from the Ashikaga period (1394–1573 A. D.).

All of the best ivory carvings of Japan are signed by the artists who made them. Tiny characters, usually filled in with red, appear in inconspicuous places on even the smallest carvings, and announce to the discerning eye of the expert that Masatoshi or Tomotane of Kyoto created the particular masterpiece.

Even in the matter of subject it is possible to recognize the work of a certain artist specializing in the portrayal of warriors, as contrasted with the work of one whose forte is the carving of demons or masks. And, as in all Japanese art, throughout this handicraft runs the touch of realism like the golden thread of Truth.

A story that the late Doctor Drummond delighted to tell (I have heard it many times from him), runs something like this:

A wealthy Japanese nobleman once said to a craftsman in bronze, who belonged to his entourage:

"I wish you to make for me a sword guard that shall depict a crane flying across the disk of the full moon."

"Very well, Master," replied the artist.

Many months elapsed before the nobleman again summoned the sword guard maker.

"And have you yet made for me the flying crane and the moon disk?" said he.

"Not yet, Master," was the reply.

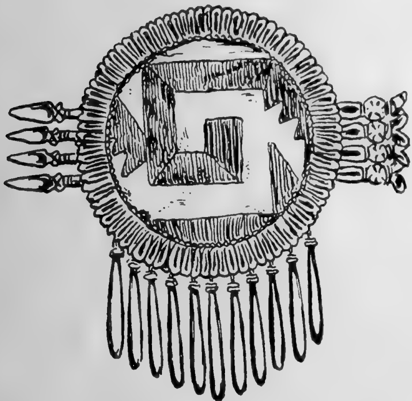
Years passed and finally the noble patron said to his servant:

"Why have you not fulfilled my wish and executed in bronze a crane flying by moonlight?"

"Master," replied this supreme realist, "every moonlit night have I watched the face of the moon these many years, but never have I had the fortune to see a crane flying across its silvery disk."

And so well did his master sympathize with the high ideals of his art that the matter was dropped and the sword guard was never made.

Guide Leaflet Series, No. 88



Artists and Craftsmen in Ancient Central America

By George C. Vaillant

THE AMERICAN MUSEUM OF NATURAL HISTORY
NEW YORK, 1935

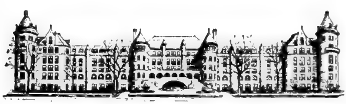
ARTISTS AND CRAFTSMEN

in

ANCIENT CENTRAL AMERICA

by

GEORGE C. VAILLANT
Associate Curator of Mexican Archaeology



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THE FEATHERED SERPENT
Detail from relief at the temple of Quetzalcoatl, Teotihuacan, Mexico. Teotihuacan is the site of the first real civilization in the Valley of Mexico. After Lehmann, 1933

PREFACE

The seven articles, grouped in this pamphlet, are reprinted from *Natural History*. The last six appeared successively as a connected series on the art of pre-Columbian Central America. The first paper, the *Worshippers of the Aztec War Gods* came out earlier and has been included to give a glimpse of the physical and social background against which these arts flourished.

The purpose of this pamphlet is to provide examples of the extraordinary range of Central American art forms, which are too often buried in technical publications inaccessible to the general public. While there are a number of books, which describe vividly and accurately the social customs of the Aztec, Maya, and their neighbors, the high cost of reproduction has prevented a presentation of their art commensurate with its importance. In view of the considerable interest shown in Central American aesthetics, we have tried to give a general picture of art from the artistic rather than the historical point of view.

The American Museum of Natural History has in its halls of anthropology many rare and beautiful examples of human handiwork, chiefly from peoples not blessed by the term "civilized." Since anthropology is concerned with man more as a social organism than as a creator of masterpieces, presentaticn of exhibits cannot solely be confined to aboriginal fine arts. Yet it is to be hoped that through the media of articles of this nature, the visitor and student will be guided to the riches contained in the halls, the result of centuries of effort by many peoples in many lands to achieve aesthetic satisfaction.
February, 1935.

These articles are reprinted from the following issues of *Natural History*.

Vol. 33, No. 1, pp. 17–30
Vol. 34, No. 2, pp. 117–132
Vol. 34, No. 3, pp. 258–272
Vol. 34, No. 4, pp. 389–402
Vol. 34, No. 5, pp. 485–496
Vol. 34, No. 6, pp. 578–586
Vol. 34, No. 7, pp. 662–673

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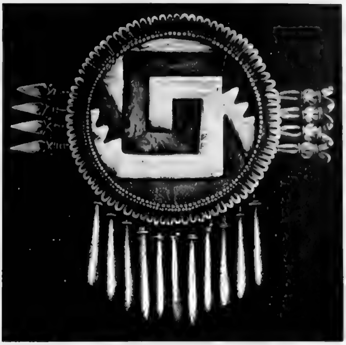


BREAST ORNAMENT OF GOLD WITH TURQUOISE MOSAIC, MIXTEC CULTURE MUSEO NACIONAL MEXICO

The Worshippers of the Aztec War Gods[1]

A Brief Description of Tenochtitlan, the Ancient Mexico City at the Time of the Landing of Cortes

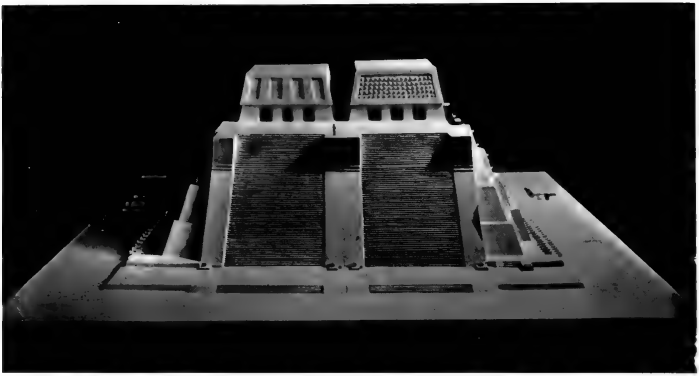
WHEN we realize that the Mayas were in a state of decadence at the time of the Spanish Conquest, and that we recreate much of the splendor of their civilization from the eloquent silence of their ruined architecture, it is well to consider the aspect of the Aztecs who were at their zenith in 1519. Although the Spaniards and their myriad allies so thoroughly razed Tenochtitlan that only a few foundations now remain, there fortunately exists much descriptive information gathered by such eye-witnesses as the Spanish soldiers and the missionary friars, as well as the testimony offered by the documents of the Aztecs themselves.

Bernal Diaz tells how his comrades-in-arms on first beholding Tenochtitlan exclaimed, "It is like the enchantments they tell of in the Legend of Amadis. Are not the things we see a dream?"

This is lyric language from hard-bitten men-at-arms whose chief avocations, while engaged in converting the heathen, lay in acquiring booty and enjoying the charms of dusky Dulcineas. Yet in contrast to the drab towns and tawny hills of Spain, Tenochtitlan must have appeared a Paradise indeed, with its green gardens and white buildings set against the blue of the lakes. "Gazing on such wonderful sights," writes Bernal Diaz, "we did not know what to say or whether what appeared before us was real, for on one side on the land there were great cities and in the lake ever so many more, and the lake itself was crowded with canoes, and in the causeway were many bridges at intervals and in front of us stood the great City of Mexico, and we—we did not even number four hundred soldiers!"

Although socially and governmentally Tenochtitlan was distinctly American Indian, outwardly it appeared the capital

[1]Drawings reproduced from the Codex Florentino, edited by Sahagun in the Sixteenth Century and published by Paso y Troncoso, Madrid, 1907.



MODEL OF THE PYRAMID AT TENAYUCA, FEDERAL DISTRICT, MEXICO

The original temple epitomizes the history of the Valley of Mexico. According to tradition, after the Tenth Century, a tribe of fierce nomads, the Chichimecs, filtered into the Valley and brought about the downfall of its civilized occupants, the Toltecs. The Chichimecs took over elements of the Toltec culture and began a sedentary life. Later, other tribes like the Tepanecs and the Acolhuas entered the Valley and, fusing with the Chichimecs, built up a civilization. Finally came the Aztecs, who, absorbing this Chichimec-Acolhua culture, became strong enough to dominate the Valley tribes.

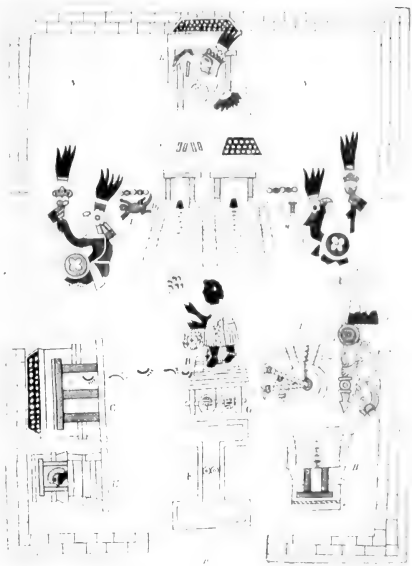
At Tenayuca six temples were found superimposed, the upper two of typical Aztec architecture. Excavations near by revealed three layers of pottery, the upper of Aztec date, the second probably to be correlated with the Tepanec-Acolhua people, and the crude styles of the lowest layer assignable perhaps to the Chichimec. While it was not possible specifically to correlate the ceramic styles with the individual buildings, yet it is very probable, to judge from the changes in the profiles of the buildings, that they were made by these successive peoples

The symbolism of the temple involves the worship of the natural forces governing agriculture. Enough stone ornaments were found to reveal the presence of two temples, one honoring the goddess of the Earth and the other the god of War, who was also connected with the Sun. The serpents ornamenting the sides symbolize the earth, and the two connected with the altars flanking the pyramid represent the 52-year calendric cycle which the Aztecs considered much as we do our century

The excavations were carried out by the Department of Prehistoric Monuments of the Mexican Government during the years 1925–32 as part of their program of reconstruction and research on their antiquities. In making this model Mr. Shoichi Ichikawa, of the division of anthropology, followed the plans of Mr. Ignacio Marquina, head of the Department of Prehistoric Monuments, under the supervision of Mr. Hay and Doctor Vaillant

city of an empire. A bird's-eye view would reveal an oval island connected with the mainland by three causeways which were pierced by bridges and which converged at the center of the city. The edges of the island were fringed by the green of the "floating gardens," while toward its center the shiny white of roof-tops predominated, the green being reduced to the little squares of the patio gardens. Thrust above the quadrate masses of the roof-tops loomed the various clan temples, each set on its pyramid. There were few streets or open spaces in the city, which was gridded with canals crossed by drawbridges but the plazas of the temple of Tlaltelolco and of the religious center of Tenochtitlan stood out from the pyramids and official palaces clustered about them. There must have been a curiously living quality about this grouping, the temples seeming to ride like horsemen among the serrated ranks of the houses.

A visitor would be struck by the rich variety of the sights were he to transverse Tenochtitlan from south to north. Approaching along the causeway, the



SAHAGUN'S MAP OF MEXICO CITY

A.—GREAT TEOCALLI OF HUITZILOPOCHTLI AND TLALOC. B.—PRIEST OFFERING A SACRIFICE. C.—PRIEST QUARTERS. E. EAGLE WARRIORS' QUARTERS. F.—BALL COURT. G.—SKULL-RACK. H.—TEMPLE OF XIPE. I.—SACRIFICIAL STONE, POSSIBLY STONE OF TIZOC. K.—TEMPLE OF HUITZILOPOCHTLI, THE ORIGIN PLACE OF WORSHIP OF THIS GOD. LATER BUILDING "A" SUPPLANTED IT. L.—5 LIZARD (DATE) AND STATUE OF MACUILXOCHITL, GOD OF FLOWERS. M.—5 HOUSE (DATE) AND STATUE OF MACUILXOCHITL, GOD OF FLOWERS. N.—DANCING PLACES, THREE ENTRANCES TO THE TEMPLE ENCLOSURE ARE SHOWN IN THE SURROUNDING WALL, WHICH WAS ADORNED WITH SERPENT HEADS

traveler of that time passed first between expanses of open water. Then gradually tiny islands of green appeared, the so-called floating gardens, made of masses of mud heaped up from the bottom of the lake and spread on reed rafts. White-clad farmers dexterously poled their tiny dugouts through the maze on their way to cultivate their garden truck. These irregular islets merged gradually into orderly groups, where the roots had established anchorage in the lake bottom and made more solid ground. Open water remained only in the narrow canals. Save for the broad causeways, roads there were none, and along the waterways one saw in increasing numbers boatloads of produce headed in toward the city. Here and there among the green one caught glimpses of thatched roofs and wattled walls, the huts of the farmers. Then adobe walls of more substantial dwellings began to encroach on the gardens, and the waters of the lake shrunk to a canal following the roadway. The adobe walls gradually were replaced by the fronts of houses plastered white or with the rich dull red of powdered pumice. For the first time the visitor realized how the city expanded through the artificial creation of beds of vegetation which in solidifying bore first a crop, then a modest hut, and finally became integral with the masonry of the city.

The causeway had now changed from a simple means of communication into the social complexity of a principal street. Since canals took the place of roads, space for a saunter was so rare that the causeways were as much recreation grounds as arteries of traffic. Thus people out to see the sights, people on errands, people on the way to the myriad functions of religious import swallowed up the long lines of trotting carriers who, bowed under their burdens, went to the city with produce and tribute, or left it with goods for barter. Outside the city limits the ant-like streams of laden folk had been but rarely relieved by the rare passage of a civil functionary, all feathers and pomp in his litter, or of a stern merchant with a handful of fighting men followed by a chain of apprentices, showing the whites of their eyes as they peered from under the press of the tumplines.

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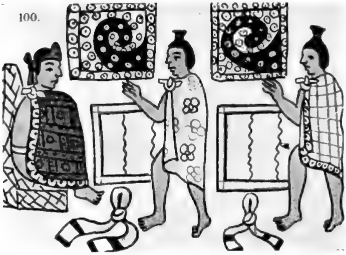


INVESTITURE OF WARRIORS WITH TRAPPINGS OF CASTE

Now could be seen men in rich mantles, sniffing flowers as they watched the milling crowd and black-robed priests whose hair was matted with the blood of self-inflicted penance. There was little sound, there was little hurry, save for the carriers, trotting to reach relief from their burdens. But there was great vitality, that of a multitude of units participating in complex action, knowing each its allotted part but not the substance of the whole.

A glance into the doorway of a dwelling gave relief from the cold-blooded, almost insect-like quality of the life outside. A shaded patio was blocked in with buildings with cool and spacious interiors. Mats and straw cushions on the polished floor welcomed one to repose, while the rhythmic clap of hands and the scrape of stone on stone told that tortillas were being made and corn meal ground in a kitchen at the back. In a corner an elderly man was talking to two small boys, whose serious faces showed that, already conscious of their participation in the tribal life, they heeded their uncle's precepts. In a doorway a fat little girl vainly tried to imitate with her stubby fingers and toy instruments the graceful movements of her mother as she produced fine thread by the cunning manipulation of her spindle. Lolling on a

Photograph from Ewing Galloway

THE "FLOATING GARDENS" OF MEXICO

A scene that might well represent the days before the Conquest. The people in the district of Xochimilco, where this picture was taken, still speak Aztec and live much as did their ancestors

Photograph from Ewing Galloway

THE ZOCALO, MEXICO CITY

The site of the ancient temple enclosure of Mexico as it looks today. The Cathedral is built in front of the great Temple of Huitzilopochtli.

cushion, a young man idly smoked, picking thoughtfully at the scarcely healed lobe of his ear, tattered by penitential blood-letting with cactus spine and obsidian blade.

A fiesta was going on in another house and one heard music, the rich vibration of wooden drums and the gay squeal of reed flutes. The patio was full of people gay in the bright colors of their holiday clothes, and the air was heavy with the cloying scent of lilies. The sharp smells of rich sauces cunningly mixed from many peppers embroidered this odor, and occasionally a light breeze wafted the cool, mystic scent of incense. Somebody was celebrating his birthday, since in the background one saw a painted figure adorned with maguey paper representing the titulary deity for the day. A little apart from the feasters who partook of their entertainment with dignified pleasure, clustered a group of old men whose clownish gestures and burlesque solemnity could be easily associated with the cups that a slave was industriously filling for them. Not for nothing had they passed through the rigid self-denial of young manhood to be permitted alcoholic indulgence in their old age, whenever a feast came around. A last backward glance revealed the musicians, garlanded with flowers, blowing their flutes and conch shells, while one beat on the head of a cylindrical drum and another the wooden tongues in the side of the two-toned *teponaztle*.

Farther up the street the priests seemed to increase in numbers and more individuals wore the trappings of high office, such as the nodding panaches of quetzal plumes, and cloaks the designs of which were worked in feathers like the clan insignia on their circular shields.

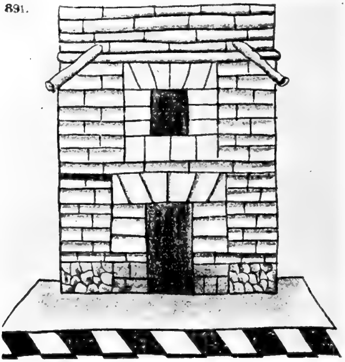
Presently the causeway ended in a great open square where rose the majestic planes of the pyramids. In the hard, bright light of early afternoon, heat waves joined with smoke of incense in rendering

902.

House of Wattle and Daub, Used by the Poorer Farmers

indistinct and unearthly the outlines of the temples, and the short, black shadows suggested unspeakable things. Was it imagination or reality, that sickening odor of a filthy butcher shop, in bitter contrast to the immaculate pavement of the courtyard? Imagination was too personal a sensation for an Indian community and the great block of the skull-rack gave the answer. Thousands of skulls were piled up in orderly symmetry, and the blacks of the eye sockets and nostrils of these sacrificed victims suggested heaps of infernal dice. A few young men were practising in a ball court near by, thrusting at the ball with agile hips while striving to propel

891.



Two-Story House of Stone and Adobe

it through the rings set transversely to the walls along the length of the courts.

A circular stone set a short distance away was the scene of a most cruel game. Here on certain ceremonial days a tethered captive was allowed to defend himself with a wooden club against the onslaught of an adversary whose weapon was set with razor-sharp obsidian blades. Sometimes a victim would resist so successfully that he gained a pardon. The great disc of the calendar stone was

889.

A Noble's House. Note Fresco and Stone Columns

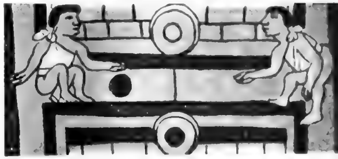
placed vertically on another platform. Carved with consummate mastery of design, it represented the symbolic history of the world. A third great disc, carved on its face and edges, commemorated the far-flung conquests of the War Chief Tizoc.

A sacrifice was to be made. Before a small temple dedicated to one of the gods, a group was gathered, some in the gay panoply of merchants and others wearing the sinister black of the priesthood. Among them, tightly-pinioned, stood a slave, who looked unseeingly about him, resignation, not fear, in his face. The priests rushed him up the steep steps to the temple, the merchants following at

more leisurely pace. Two priests, seizing the slave by either arm, forced him backward while two others pulled his legs out from under, until his body curved, belly upward, over the altar. A fifth priest dragged his knife in a long sweep from the breast-bone to the base of the stomach and, reaching into the aperture, with a dexterous twist tore out the heart. They burned this on the altar, and the merchants, swinging long ladles of smoking incense, chanted their thanks for a safe and profitable excursion to the hot country.

BOYS GOING TO SCHOOL. NOTE THAT THE PARENTS WEAR THE DRESS OF POOR FOLK

Paying no attention to this pious little scene, knots of chiefs were converging on a large building at a corner of the plaza. The War Chief Montezuma was planning an attack on a neighboring town remiss in its tribute and there must be a gathering of the clan leaders. Adorned with helmets like the heads of jaguars, eagles, and wolves, girt with armor of wadded cotton brocaded in many colors or embroidered with feathers, their faces set with nose and lip ornaments of jade and gold, these fierce-faced chiefs passed through the door, but before entering the council chamber they stripped off this finery.

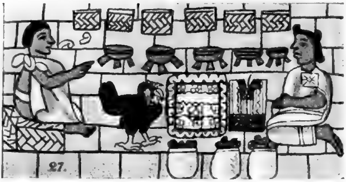


A BALL COURT. THE POINT OF THE GAME IS TO PASS THE BALL THROUGH THE RINGS

Then bare-headed and barefooted, with downcast eyes, they made their way before the throne where sat the slim figure of Montezuma the War Chief, who was simply dressed but for the jade earrings and gold crown of his exalted office.

The austerity of the council chamber was not borne out by Montezuma's other apartments, which contained all the appurtenances of luxurious potentacy. Magnificent quarters were occupied by the War Chief's two wives and his many concubines. Kitchens and store houses were spread over another great space, for

WARRIORS. NOTE RICH TRAPPINGS AND VICIOUS CLUBS OF WOOD, TOOTHED WITH OBSIDIAN



A PRODUCS MARKET. THE NEAT ARRANGEMENT OF WARE MAY BE SEEN IN ANY MEXICAN MARKET TODAY

not only were some three hundred guests served at each meal but also a thousand attendants and guards. In contrast to the profusion within, outside the kitchen door squatted patiently a meager group of countrymen from whose carrying bags swayed the mottled heads of trussed turkeys to be offered to the larder.

Other apartments in Montezuma's palace contained the tribal treasure composed of the tribute wrung from many pueblos. Gold, jade, rich feather mantles, baskets of produce were heaped in abundance. Clerks were listing the goods to see that each subject town had contributed its

A GROUP OF JUGGLERS. OBSERVE THE HUNCHBACKS IN THE LOWER ROW

quota, or calculating the share that should be turned over to the various clan stewards. Another patio presented a more animated scene. Here acrobats were practising their feats and poor, warped dwarfs were composing grosser contortions to win a chiefly smile. In another set of buildings was housed the zoo, where serpents undulated sluggishly, and where from behind wooden bars peered the greedy, yellow eyes of jaguars and ocelots. In a side room, a human

PUNISHING MALEFACTORS. FOUR JUDGES SUPERVISE EXECUTIONS BY NOOSE AND CLUB

hand projecting from a basket of raw meat showed how the bodies of some of the sacrificed victims were utilized.

Extending north from this great plaza which even today is the center of the city, stretched the highway to Tlaltelolco. This wide road with a canal beside it was filled with the same indecisive multitude that filled the southern artery. The sinking sun had brought people out on their roof tops. Some leaned over parapets to watch the throng below, even as idlers squatting in a shaded bit of the street took equal interest in the slow movements of the householders above them.

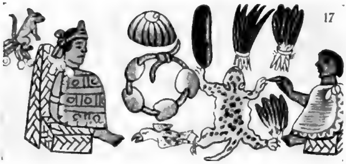
A path and canal debouching into the main avenue led to a small square, in the

STAIRWAY OF THE PYRAMID OF TENAYUCA
Near Mexico City. This is an excellent illustration of the dramatic quality of Aztec architecture

center of which loomed a pyramid. From the patio of a large building shrill cries arose and the dull clash of wooden instruments. Within, a number of boys were receiving instruction in the manual of arms. Each equipped with a small buckler and a flat club of wood, they learned the art of cut and parry under the scornful eye of a warrior. They dealt and received severe blows, but the clubs were not toothed with the wedges of obsidian, the volcanic glass that made hand-to-hand combat so vicious in war. Another group were practising with the atlatl or throwing stick. The marksman laid his spear along a narrow wooden trough hooked at the farther end, the nearer end being grasped in the hand. By lengthening the arm in this way it was possible to attain a greater propulsive force.

A less animated scene took place among the boys of the religious training school on the other side of the plaza. Their little legs and faces lacerated by maguey spines, their bodies thin from penance, and their eyes dulled by the monotony of self-denial, these children were chanting strophes from a ritual. The preceptor who led the singing showed in his own scarred and emaciated body that the propitiation of the gods was a relentless and never-ending task. Priest, chief, warrior, or husbandman, every Aztec from boyhood on, spent much of his life either in a kind of beseeching penance to ensure his future or in a state of grateful atonement for not having had a worse past. The Aztecs lived on intimate if uncomfortable terms with the supernatural powers.

Another aspect of this lack of individualism was to be seen in the tecpan or clan building. Here elders of the clan were arranging the affairs of the group. One old man by means of maps adjusted a question of land tenure between two contesting families, making his judgment on the basis of how much land each family could cultivate by its own efforts.



TRADE FROM THE HOT COUNTRY. JAGUAR SKINS, JADE, AND FEATHERS ARE OFFERED FOR SALE

Another old man was distributing some pottery, given up as tribute from a town across the lake, to some of the poorer members of the community. None of these people bestowed more than an occasional glance into the back courtyard where an adulterer was being stoned to death by the members of the affronted family. Urban existence contained too many interests and life was too cheap for them to view as an excitement the inevitable result of wrongdoing.

TRADE FROM THE HIGHLANDS, GOLD, COPPER, OBSIDIAN, AND MANTLES ARE OFFERED IN EXCHANGE FOR TROPICAL PRODUCTS

In many such centers each phratry regulated its own affairs. The great plaza where Montezuma had his palace and where the gods were worshipped in many temples was for the use of all the clans together. Yet in spite of the importance of this center, the great plaza of Tlaltelolco near the northern edge of the island was almost as striking. The self-contained nature of a Mexican tribe did not diminish the governmental functions of a conquered people, who were supposed to furnish fighting men and tribute, once they acknowledged the sway of a superior power. Thus the recently conquered Tlaltelolco had a communal center as majestic as that of Tenochtitlan. It seemed more dramatic to Spanish eyes, perhaps because its great temple to Huitzilopochtli was thrust into prominence by the wide spread of the market place, while in Tenochtitlan the great buildings were so close together that it was hard to gain an impression of their size.

The open space was divided into two sections. A large area of smoothly polished pavement was bordered by arcades which sheltered many of the merchants. At one edge was a basin opening from the canal beside the northern causeway, where the boats bringing goods and produce could find an anchorage. Each kind of product was concentrated in a special place. Thus one section was devoted to vegetables, and compactly squatting women sat watching their goods, which were arranged in symmetrical heaps on woven mats. In

A SLAVE FAMILY. THE BARS ACROSS THE NECKS ARE THE SIGN OF BONDAGE

another section cotton mantles were being sold, some being spread to show the full design, and others neatly folded. Elsewhere was a row where tools were for sale, obsidian blades, spindle whorls of pottery carved and burnished, spoons of deer horn, bodkins of bone, and a few copper axes. A brilliant mass of color characterized the row of the feather salesmen. Some sold merely bunches of the feathers, the green of the trogon and the multicolored plumage of the parrots, while at the booths of the others cloaks, mats, and shields gave evidence of charming fancy and patient toil. Jewelers displayed ornaments of jade and gold worked into precious rings of filigree or massive, beaten gorgets. It was the jade, however, that caught the envious eye and was produced with furtive circumspection as material of great price. Other merchants sold ornaments of shell, and the pinks, whites, and subtle mottled browns of sea shells contrasted with the rich, dark sheen of the tortoise carapace. At one booth a rich warrior earnestly chaffered with the proprietor for an exquisite pair of earplugs,

80.

Feather Workers. In the Distance a Merchant Brings the Raw Materials from the Tropics

53.

Gold Worker Making a Mosaic Design Like the Breast Ornament on Page 5

cunningly inlaid with a mosaic of turquoise and shell.

The smiling whispers and admiring glances of the crowd when at the jewelers' abruptly changed in the slave quarter to appraising stares. Some of the chattels wore wooden collars and stared blankly with brutish eyes. These had reached their servitude through penalties for crime or by capture in war. Others were thin and emaciated, and did not wear the collar of bondage. They had met with misfortune and were selling themselves to ensure food and shelter.

A low hum rose from the market place; there was none of the strident shouting of a European fair. The bargaining for goods was carried on slowly, quietly, but none the less keenly. The Aztecs had no money, so that barter was the usual means of purchase. The cocoa bean, however, had a standard value and this, in equalizing exchanges, performed the nearest approach to the function of currency. Passing through the crowd were warriors who acted as police, and should a dispute arise, they haled the disputants to a court where one of the tribal elders settled the question.

96.

Farmer Planting Corn. Note the Use of the Planting Stick

Beyond the market was a double line of walls which divided off the religious part of the plaza of Tlaltelolco from the market. Rectangular buildings, with patios in their centers, housed the priests and the various schools and councils of the central organizations of the Tlaltelolcans. Farther on were grouped the main temples of the various divinities. In the center the great temple shouldered its bulk into the sky. There was a skull-rack like the one in Tenochtitlan, and another heap was made of the bones of the victims. Near the great pyramid stood a circular temple, the door of which was built to resemble the mouth of a serpent: the place of worship for the god Quetzalcoatl. The sacrificial block in front was black with the smoke of incense and the encrusted blood of victims. A pile of stone knives and axes gave a sinister indication of what rites were practised there.

Pools of water fed by pipes from the aqueduct gave an impression of quiet peace and the reflections of the temples, distorted by an occasional breeze, intensified the brooding mysticism of the sacred enclosure. As a relief to the austerity of the scene young girls with downcast eyes slipped back and forth on the various errands of their training school within the enclosure. The great pyramid, that of Huitzilopochtli, the war god, completely dominated the place. Terraces breaking at intervals the line of the sloping sides increased the impression of its size. A wide staircase of one hundred and fourteen narrow steps led up the western side, and so steep was this stair that not until one's head rose clear of the platform, did the temple itself come into view.

The temple was, in reality, two shrines, built side by side, each having stone walls and soaring roofs of wood. Through the right-hand door, one could dimly see the squat figure of Huitzilopochtli carved in stone and then covered with a paste in which were set jade, turquoise, gold, and seed pearls. A girdle of snakes in gold picked out by precious stones adorned its waist, and around its neck hung a string of gold masks with turquoise mosaic. By its side stood the statue of an attendant deity with a short lance and a gold

101.

Farmer Storing Corn for Winter. Pottery Jars Like Those Shown Here Are Used for Storage Today

A Fiesta. Here A Drummer and Singers With Rattles, Flowers, and Feather Fans Make Merry

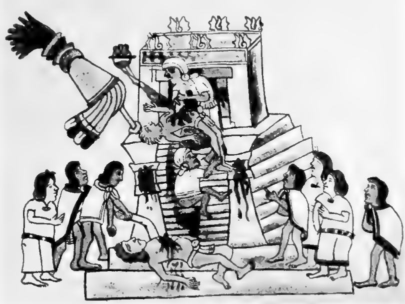
Musicians Singing a Duet. The Scrolls Here Show the Lilt of Song. Note Details of Drum and Rattle

shield richly decorated with a turquoise mosaic.

In the other temple was an image of Tezcatlipoca, one of the most prominent Aztec gods. Its eyes were inlaid with mirrors of obsidian that gleamed reddishly in the afternoon light. This statue, too, was adorned with gold and precious stones. High in the wooden roof of the temple was a small statue of the god of seedtime. Braziers of incense discharged greasy coils of smoke which plunged into deeper gloom the temples whose walls were already black with the blood of many victims. In dim corners stood heaps of paraphernalia, conch-shell trumpets, knives, banners, and baskets of shapeless human hearts that had not yet been placed upon the braziers. The priests gliding in this murk seemed fitting satellites to the diabolic gods they served. In front of the temple stood the great drum that was soon to throb across the lake the death throes of a nation.

It was from this point that Montezuma showed Cortes his empire, and Bernal Diaz, who witnessed the scene, has left an unforgettable description, which is the best conclusion to this brief sketch of Tenochtitlan, the ancient Mexico City.

"Then Montezuma took Cortes by the hand and told him to look at his great city and all the other cities that were standing in the water and the many other towns and the land round the lake. . . . So we took looking about us for that huge and cursed temple stood so high that from it one could see over everything very well and we saw the three causeways which led into Mexico . . . , and we saw the (aqueduct of) fresh water that comes from Chapultepec which supplies the city and we



Priests, Men, and Women Witnessing Human Sacrifices at the Shrine of the Warrior God Huitzilopochtli

saw the bridges on the three causeways which were built at certain distances apart . . . and we beheld on the lake a great multitude of canoes, some coming with supplies of food, others returning loaded with cargoes of merchandise, and we saw that from every house of that great city and of all the other cities that were built in the water it was impossible to pass from house to house except by drawbridges which were made of wood, or in canoes; and we saw in those cities Cues (temples) and oratories like towers and fortresses and all gleaming white, and it was a wonderful thing to behold!"

CAST OF THE NATIONAL STONE

AN AZTEC SCULPTURE WHICH MIGHT BE CALLED A MODEL, SINCE IT PROBABLY REPRESENTS THE CALENDAR STONE SET ON A PYRAMID. THE ORIGINAL IS ABOUT A METER SQUARE AND IS RICHLY ADORNED WITH CARVINGS PERTAINING TO WORSHIP OF THE SUN GOD.

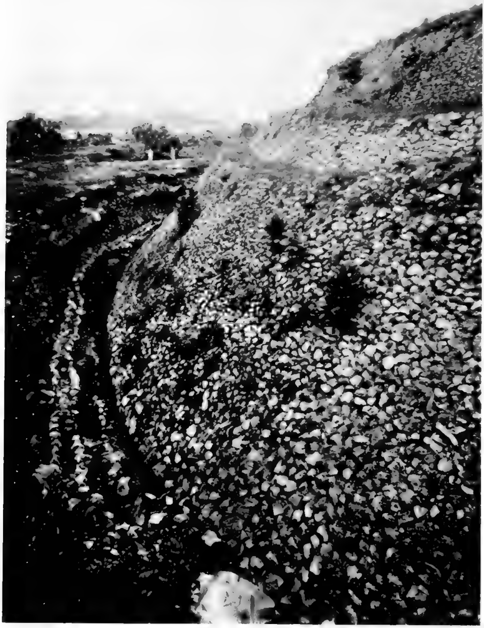
Temple, Nahua Style, Santiago Huatusco, Vera Cruz. After Dupaix, 1834

The Architecture of Pre-Columbian Central America

THE art of Central America is as baffling as it is impressive. Completely a product of the Indians of the New World, it cannot be fitted into the customary canons of European aesthetics. The higher expressions of Central American art are far from primitive, the modern American, missing the emotional appeal of his own art, feels something remote and undeveloped in Pre-Columbian civilizations. Yet, since we ourselves are immigrants in a new land who built up our own civilization, the cultural and artistic achievements of previous immigrants, of different race, to the same continent should be as worthy of our knowledge as the culture of the ancient Egyptians, which is part of all our courses in ancient history.

In the preceding chapter we have tried to describe the life in a typical Central American community and in the following pages the art that flourished amid such surroundings, in an effort to bring into sharper focus the more tangible aspects of Central American art. But before we begin to discuss these various manifestations, let us roughly sketch the historical background of these civilizations.

The first immigrants from Asia entered America by way of Alaska toward the close of the last glaciation, and this infiltration of peoples probably continued up to the time of European colonization. Since no traces of Asiatic civilization are found in North America, the cultural plane of which is relatively low, there are no good grounds for assuming that these immigrants brought an art with them. At some time during this population of the New World, groups of people in Central America and northern South America began to develop an agriculture based on



Photograph by LaRochester, Mexico

PYRAMID OF CUICUILCO, VALLEY OF MEXICO

This oval structure of adobe studded with uncut stone is completely surrounded by the lava flow at the left. It is probably the oldest building in Central Mexico

native plants like corn, potatoes, and manioc, which were unknown to the Old World until after the discovery of the New. This food supply is one of the most important proofs that the New World civilizations were uninfluenced by those of the Old. A contact with the Old World close enough to permit absorption of its art styles would also utilize its food plants and domestic animals.

Once a stable food supply was assured them, the tribes in Central America had an opportunity to develop their culture. Perhaps more conscious of the novelty of agriculture than the Asiatics, the Central Americans worshipped those natural forces which controlled the harvest, and evolved a religion in their honor.

The broken mountainous country stretching from the Rio Grande to Panama has several distinct climates, according to the altitude. Great forests and mountains tended to isolate inhabited communities. Consequently small groups of people could retain their language and develop dialects as well as evolve distinctive customs and art forms. Some of these tribes developed most sophisticated civilizations, while others lagged, retaining a primitive culture. To thread our way through the tortuous mazes of the cultures of these tribelets is beyond our purpose, nor have we the knowledge to do so even if we wished.

Two major artistic developments can be discerned, however, the art of the Maya-speaking people of the low, hot country of Guatemala and Yucatan, and that of the Nahua tribes of the Mexican Highlands. Combinations and transitions between Maya and Nahua art may be seen in the civilizations of the tribes in adjoining regions. Maya art is the aesthetic of a gentle people, whereas Nahua art is the product of a more austere and warlike folk.

The period of Central American art covers the first fifteen hundred years of the Christian era. Previous to that time

Photograph by S. G. Morley

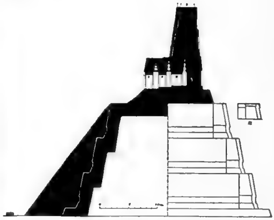
TEMPLE EVII SUB, UAXACTUN, GUATEMALA

This oldest Maya building yet found is made of rubble with a plaster covering. It is a platform without any trace of a temple. Note the masks carved at the sides (See p. 57)

the tribes of Central America were making the slow climb from a hunting stage and inventing agriculture anew, while some of the Old World nations had already embarked on the preliminary stages of civilization. The Maya seem to have been first to produce a really fine art in Central America, but, by the Tenth Century, the Nahua had also developed a concrete aesthetic expression. While in the first ten centuries of the Christian era the Maya were artistically predominant, they afterward began to decline, so that at the time of the Spanish Conquest in 1519, Nahua tribes, like the Aztec and Mixtec, produced the major examples of Central American art

Having roughly oriented ourselves in time and space, we can now examine the various expressions of Central American aesthetics. We can appreciate a little more clearly the circumstances under which groups of people, without steel tools and without draught animals, were able to create a civilization that glorified not themselves but the gods who permitted them to exist. Living in subservience to their divinities, the Central Americans seemed little interested in their own emotional weaknesses or sentimentality, and this impersonality, often austere, defines their art.

Architecture, more than any other art, symbolizes the pitiless quality of Central American civilization. However, as coldness also characterizes our own modern buildings, the architecture of the ancient Mexicans and Mayas gives us the most comprehensive approach to their art. We can also understand, since the major architecture of Central America is dominantly religious, how ritualistic and ceremonial requirements permeate the other arts like sculpture, painting, textiles, jewelry, and pottery.



TEMPLE II, TIKAL GUATEMALA, MODEL AND SECTION

The decorative emphasis has passed from the platform (p. 21) to the temple proper. The rooms are mere slits in the solid masonry mass supporting the roof comb on which decoration is concentrated. It can be readily seen that the basic idea is to construct a monument rather than a place to house a congregation. Temple II is one of the oldest Maya religious structures, and illustrates one of the fundamental principles of the religious architecture. The succeeding photographs trace the evolution of religious monuments like this into temples. Section after Maler, 1911 (See also p. 56)

Religion was the most vigorous social force in Central America. Priests, not chiefs, governed the various tribal groups, and these hierarchs were ever conscious that they must placate the gods who controlled all natural phenomena. This philosophy caused the tribal leaders to organize ceremonies and establish places of worship in order to cultivate the favor of their divinities. Religious demands so completely absorbed the surplus energy of the Central American people, once they had met their needs for subsistence, that, except in the highest civilizations, one can discern few traces of specific civil government.

Under such conditions it is not surprising that the ceremonial architecture was tremendously developed, while dwelling houses, made of adobe or wattle and daub, were of the simplest nature. Only the Aztecs and their neighbors in the Valley of Mexico seem to have produced a domestic architecture at all complex. Discussion of the artistic evolution of architecture naturally centers around the buildings used directly and indirectly for religious purposes.

We do not know the point of origin for Central American architecture, or whether it had been evolved at a single place or in several. But the most common type of ruin comprises a group of mounds, set sometimes around a central plaza, sometimes without an obviously formal plan. Quite commonly in the mountainous regions collections of mounds are strung along ridges or mesas, which have been graded to provide level surfaces for living and to give a solid basis for the erection of platforms. Very often these terraces and substructures were faced with stone over a hearting of adobe or rubble, when a suitable quarry was readily accessible.

The groundplans of Central American cities differ, but in two respects only,—formal or informal grouping. Yet, the arrangement of the plan seems to depend

on local conditions of terrain or order of construction, rather than on the scale of cultural evolution. The architecturally very developed Chichen Itza has a haphazard distribution, while the older and structurally much simpler Teotihuacan is most elegant in its orderly design.

Preservation is an extremely important factor in our estimates of architectural values. The stone-faced temple of Yucatan which has resisted the elements seems to us more worthy of admiration than the battered adobe or rubble buildings on the Mexican Highlands which have capitulated to the elements. For all we know there may have been superb buildings of wood representing an interesting and imposing architectural order which, being incapable of preservation, is lost to us. We cannot, then, judge buildings en masse, but must trace by individual temples the course of Central American architecture.

The fundamental idea in Central American architecture was to create a focal point for ceremonies which took place outside the building. The temples were seldom intended to *house* congregations, as were the cathedrals of Europe or the great temples of Egypt, nor in shape or purpose do they resemble those colossal mortuary chambers, the Pyramids. Maya and Mexican ceremonial structures were true monuments to the glory of the gods.

In view of this dominant interest, the constant enlargement of buildings is not surprising. Moreover, in several regions, the termination of a fifty-two year cycle was the occasion for renovating all possessions, ceremonial and personal, even

RELIEF MAP OF COPAN, HONDURAS
Showing the plan of this ancient Maya city. Note the amount of grading done before construction of buildings began. After Maudslay, 1899

THE GATEWAY AT LABNAH, YUCATAN
A magnificent example of northern Maya architecture. The corbel vault is composed of overlapping stones which are supported by the weight of the masonry above, and are not united by a keystone, as in the true arch. Photograph by the Department of Historical Monuments, Mexico

to the destruction of household articles used up to that time. This aggrandizement was accomplished in two ways. The simpler method was to build over the original structure, filling in the temple and adding to the platform until both were converted into a foundation on which a new temple could be erected. Due to this custom many buildings that would otherwise have been lost are now preserved within the sheathing of the later additions. The second way was to add a wing or an ell to the original structure, a method of addition well known to us today. Sometimes the two methods were combined.

The two oldest buildings known to us in Central America were platforms, probably without temples. One of these is the oval mound of Cuicuilco in the south of the Valley of Mexico. This was built of adobe bricks arranged in several ascending terraces, and two staircases were disposed at either end. The outside of the structure was faced with river bowlders, over which a later enlargement had been made, utilizing lava blocks as a veneer. An altar in horse-shoe shape surmounted the earlier building, but no trace remains of whatever construction crowned the later mound. While it is possible that this earlier altar was enclosed, its size and shape suggest that it was built in the open. The antiquity of Cuicuilco is incontestable, first because a lava flow surrounded the building after it had been abandoned, and second, because the associated objects tie in with the remains of one of the Early Cultures of the Valley.

The other temple, Evii-sub, at Uaxactun in the heart of the Maya country, was a quadrangular structure of rubble coated with a thick layer of plaster. Stairs ascended the sides, flanked by broad buttresses carved into grotesque masks. There was no trace of any construction on top of the platform. The

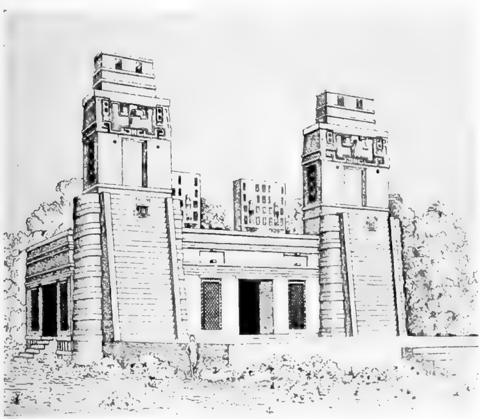
CHICHEN ITZA, YUCATAN
In this panorama of a late Maya city, may be seen how formal groundplan was seldom a primary consideration with the Maya. The temples of the Mexican period in the background show a more orderly arrangement than do the Maya buildings in the foreground. After Holmes, 1895

preservation of this perishable structure was accomplished by a later platform which effectively sealed it from destructive natural agencies, such as roots and rains. Thta temple Evii-sub is of substantial antiquity there can be little doubt, as the outer building was associated wtih some of the earliest time-markers found in the Maya area.

Both of these early structures were platforms, not temples. The underlying idea was definitely to attain elevation, and thus to dramatize the ceremony. The open summits show that there was no idea of enclosing the ritual, so that temple construction must have been a secondary factor. Already we can discern in the carved surfaces of the Uaxactun temple the Maya preoccupation with design, and in the unadorned surfaces of Cuicuilco the Mexican emphasis on mass and treatment of planes.

The need of a place to house the image of a god must soon have made itself felt, and soon the custom of a temple or shrine surmounting the mound must have arisen. The earliest Maya temples preserved were of rubble faced with plaster, and were intended to be seen rather than used. The carving which had embellished the side walls of the platform, as at Uaxactun, was transferred to the temple, leaving the substructure bare. To receive this decoration a masonry block was built on the roof, but the weight of this mass necessitated extremely thick walls to support it. Furthermore, the Maya used a corbel or false arch, incapable of bearing a heavy weight. As a result we find massive buildings with rooms only two or three feet wide.

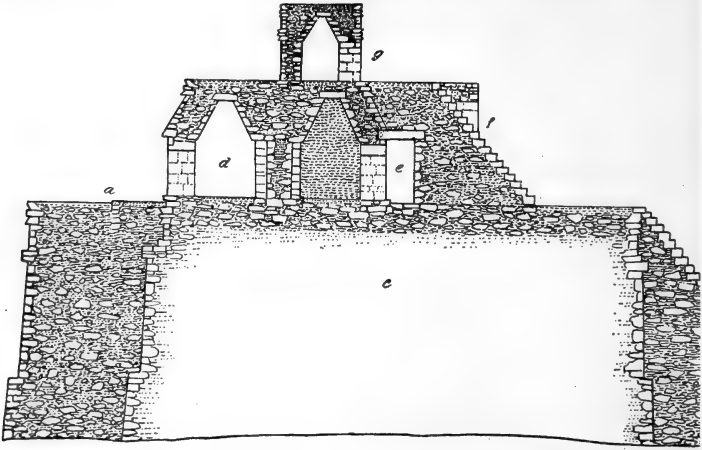
In time the Maya learned how to lighten the burden of the roof-comb by rearing a narrow perforated wall directly above the partition walls of the temple. By so doing, no weight fell directly on the arch of the roof, and it became possible to



TEMPLE AT RIO BEC, QUINTANA ROO
This Maya temple shows the transition from a religious monument to a shrine with usable rooms. The towers are conventionalized reproductions of the Tikal type of temple (p. 22), while the building proper is not unlike the Yucatan structures shown above and on page 26

THE "NUNNERY," CHICHEN ITZA

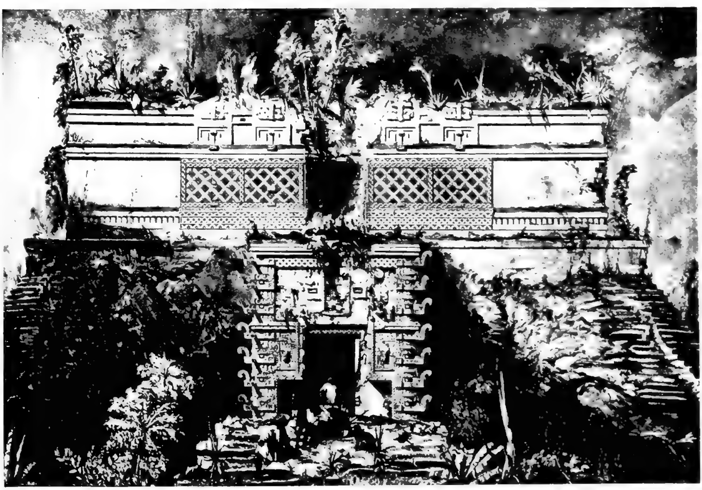
A building of Yucatan Maya type (see also p. 25, upper). Stone is used as facing and elaborate ornament relieves the outer surfaces. Note how this solid construction resists decay and renders possible an accurate appraisal of the architecture. After Totten, 1926



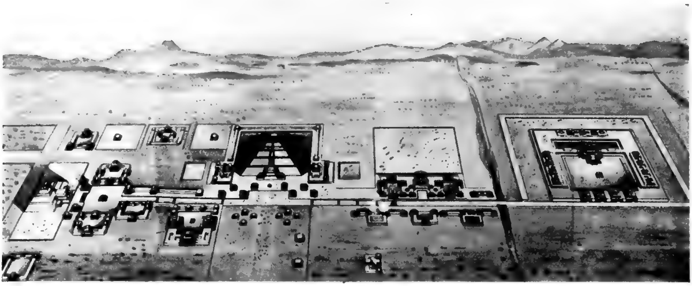
CROSS-SECTION OF THE "NUNNERY"

Showing structural detail and method of accretion. The platform, *c*, was built to add a second story, *d*, to the wing at the left of the photograph above. The third story, *g*, reached by the stair, *f*, was added later, after filling in one rank of the *d* series of rooms. After Holmes, 1895

THE CASTILLO, CHICHEN ITZA, A MEXICAN PERIOD TEMPLE
Showing this foreign influence in the dramatic treatment of the stair and the serpent columns and balustrade. The Temple of the Warriors, a notable companion building, is shown on p. 34. Photograph by Department of Historic Monuments



HOUSE OF THE DWARF, UXMAL
Compare the ornate treatment of the ornament on this Maya temple with the simplicity of the Mexican-influenced Castillo above. Note how the portal represents a serpent mouth. Totten, 1926, after Catherwood, 1841



RECONSTRUCTION OF TEOTIHUACAN

In the Toltec city of the Mexican Highlands, groundplan is very important. The temples are grouped in precincts, which in turn are arranged in axes. After Gamio, 1922

PYRAMID OF THE SUN, TEOTIHUACAN

This central structure in the panorama above is made of adobe with a stone facing and was the foundation for a temple. Note the size in contrast with the buildings near by. Photograph by Fairchild Aerial Surveys de Mexico, S. A.

TEMPLE OF THE SUN, PALENQUE
The most evolved type of Maya building. Compare the wide rooms here with the narrow slots at Tikal (p. 22). Notice also the shrine in the back room, and the division of the door into a colonnade

have wider rooms. Once room plan became a primary consideration, it was possible to give the rooms a more varied use instead of confining them to the support of a heavy roof-comb. At Palenque we find an outer and an inner shrine, the latter containing a small sanctuary, and at the Castillo in Chichen Itza an outer corridor surrounds the shrine. The culmination of the temple idea is the great Temple of the Warriors at Chichen Itza and its various annexes. Here the roof-comb was dispensed with, and rows of elaborately carved columns supported a series of arches. This building, strongly affected by influence from Mexico, is the most important Central American example of a temple which afforded space for a congregation within its confines.

The essence of Maya architecture may be seen in the evolution of the offering platform into a pyramid surmounted by an ornamented shrine which finally, through increased knowledge of construction, is developed into a temple. Paralleling this development is that of the associated buildings which presumably were to house the temple staff. Without the necessity of supporting an elaborate ornamental crest, the rooms could be as wide as a corbel vault could conveniently be made, a space of some eight to thirteen feet, depending on the length of the tails of the roofing stones and the height of the vault. But the long axes of the building could be indefinitely prolonged. At first these houses seem to have been composed of three or four oblong rooms fitted together to form a rectangle. Later, when size began to be more esteemed, ranks of rooms were strung together like beads.

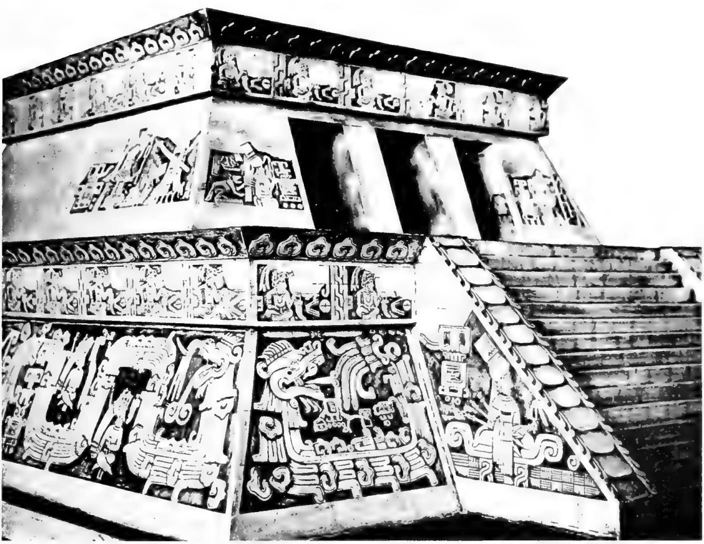
The highest development of this kind of building was found in Yucatan. Instead of a plaster façade, the facing of these houses was of stone, which was elaborately carved. The general field of decoration was between the top wall and the roof. Now a large building of several ranks of rooms was extremely unsatisfactory, since the inner rooms were deprived of light and air. To overcome this, the idea of creating second and third storys was

THE GREAT TEMPLE AT TENOCHTITLAN, THE ANCIENT MEXICO CITY
This building and that on page 27 show the Mexican emphasis on planes in contrast to the Maya use of ornament. The double temple is in honor of the Rain and War Gods. (See NATURAL HISTORY Volume XXXIII, pp. 18–19). Reconstruction by Ignacio Marquina

evolved. As we have seen in the temple architecture, it was incompatible with Maya idea of safety to support a great weight on a hollow foundation. In building a second story the Maya usually filled in the rooms immediately beneath the projected upper floor. To keep the maximum number of rooms in use, each of the rooms was stepped back from the one below. Another method of constructing an edifice of more than one story was to surround with ranks of rooms the platform supporting a building.

We have seen that at first the conception of an enclosed space was predominant, and that later air and light began to be considered by erecting several tiers of rooms. As a corollary of this, the simple doorway began to be split up into several portals, leading to an eventual evolution of the column. Toward the close of the Mexican occupation of Chichen Itza, the ranks of rooms so characteristic of Yucatan gave way to colonnades. Here wooden lintels strung from column to column carried the weight of the vaults.

HALL OF THE COLUMNS, MITLA, OAXACA
This is one of the largest completely walled buildings in Central America. Note the ingenious mosaic of separate blocks of stone. After Charnay and Viollet le Duc, 1862



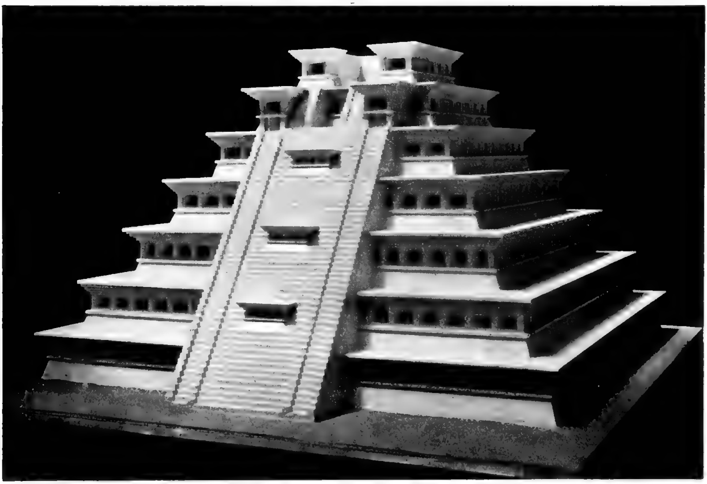
TEMPLE AT XOCHICALCO, MORELOS
Another ornate example of Nahua architecture wherein the temple and platform are treated as a unit. The frieze falls into the Mixtec-Zapotec art style. After Totten, 1926

Perhaps because of accident of preservation, but more probably because of increased light, in buildings of this late period we begin to find interior ornament such as frescoes and carved and plastered columns. Unless designs could be seen, there would be no purpose in creating them, for the inner apartments of a simple collection of ranked rooms must have been almost pitch black.

The essential success of Maya architecture from the dramatic point of view was the invention of a monolithic type of construction involving the false arch, which rendered it possible to combine mass, height, and field for ornament, with inner space for the performance of cult practice. On the highlands of Mexico the basis of construction was much simpler. The false arch was unknown, and there was no such mastery of stone and concrete construction. Unfortunately, very few Mexican temples have been preserved.

In the first place, the people on the Mexican Highlands commonly used adobe and piled stone faced with cement, a type of construction that resists very poorly the destructive action of time. Instead of covering their buildings with corbel vaults, they erected flat roofs of plaster spread on beams, or pitched roofs of thatch or wood. Consequently we have no such obvious point of interest as in the miraculously preserved Maya buildings. However, one does have the impression that the effect of awe was gained by the vast, imposing mass of the substructure rather than the building on top.

Decorative treatment of the side walls of the platform was emphasized very rarely to the point of obscuring the central planes. While the most ornate frieze known from the Highland region is the deeply cut Temple of Quetzalcoatl at Teotihuacan, more often carvings like snakes' or death's-heads were inserted in

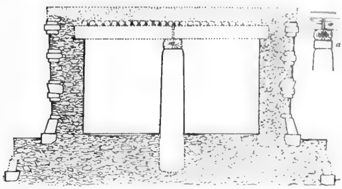


TEMPLE OF TAJIN, VERA CRUZ

As at Xochicalco (p. 31) the platform and temple are built as a unit. The apertures are small niches for statues. This temple is most readily adaptable to European architectural ideas

the walls. The major ornament seems to have been the stair which was treated as a center of interest and not as a mere communication.

The plans of the temples were not so rigidly controlled by structural factors as in the Maya area. Roofs supported by wooden beams could cover wider spaces than stone slabs inched out to meet in a corbel vault. Under such circumstances an inner and an outer chamber of substantial size could be made. Sometimes the temples had stone walls and the roofs were lofty structures of wooden crib-work. A feature of many Aztec temples was the erection of two temples on a platform for which ever two gods in their pantheon were especially to be venerated. At Tenochtitlan there was a notable pair of shrines in honor of the Gods of War and Rain.



CROSS SECTION OF A TEMPLE AT MITLA, OAXACA

(See p. 31 upper)

Compare this Mexican roof with the corbel vaults of the Maya (p. 26 lower). This structural method makes it possible to have wider rooms than under the Maya system. After Holmes, 1897

Palaces and priestly dwellings followed domestic architecture more closely. A number of rooms were grouped around courts, and colonnades were not uncommon. In some places, as at Teotihuacan, by using interior columns a large central room could be formed. Two-story houses are described in accounts of Mexico, but at the earlier site of Teotihuacan, our best source for priestly dwellings, platforms were used to elevate one room above another. As in the Maya area, there was the same mistrust of using the roof and walls of one room to support another.

A blending of Mexican and Mayan architectural ideas existed at Chichen Itza and at Tuloom. At Chichen Itza the Castillo showed a dramatic treatment of the substructure and stair, although the emphasis on the temple was in part Maya. More specifically the Temple of the Warriors resembled Mexico in the ornate friezes around the platform, and perhaps the use of the colonnade in the temple proper. However, the vaulting and general exterior treatment are Maya. At Tuloom we find an emphasis on mass and plane surfaces, as well as the flat roof of the Highlands. Conceivably this is the ultimate southeastern swing of the Mexican school of architecture.

These types of architecture, the Maya and the Mexican, express the two major styles of Central America. There are, however, certain other buildings which suggest the existence of different architectural evolutions.

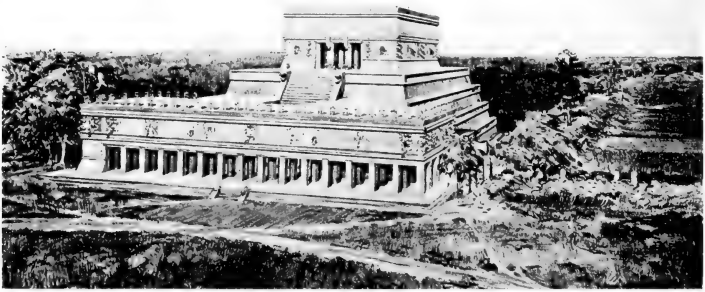
Especially notable is the temple of Tajin near Papantla in Vera Cruz. In this case the temple was made one of the successive rising stages of the platform, thus creating a unified harmony between fane and substructure. There was no carving, although in niches set throughout the sides idols were placed; but these cannot have detracted from the essential unity of plane and mass. Another case where the temple was treated in terms of the platform was at Xochicalco. Here the planes of the building were subordinated as fields for an exquisitely carved relief, which suggested a Maya inspiration.

At Mitla, in Oaxaca, we have the three great "Palace" groups, each composed of oblong buildings on the three sides of a sunken court. The walls were ornamented

TULOOM, QUINTANA ROO, A FUSION OF MEXICO AND MAYA ARCHITECTURE. AFTER LOTHROP, 1924

with a mosaic of cut stones composing a lovely fretwork design. The flat roofs were partly supported by massive stone columns, and include the largest completely walled floor spaces found in Central America.

This résumé has covered briefly the principal aspects of Central American architecture. Maya architecture emerged as triumphant glorification of design, as opposed to the Mexican emphasis on massive planes. Certain specialized buildings were mentioned which although belonging to neither of these major styles, were none the less noteworthy. At the same time it must not be forgotten that Central America is spattered with mounds, the details of which are either irremediably destroyed or else have to be studied by excavation, so that only the broadest outlines of Central American architecture are visible to us.



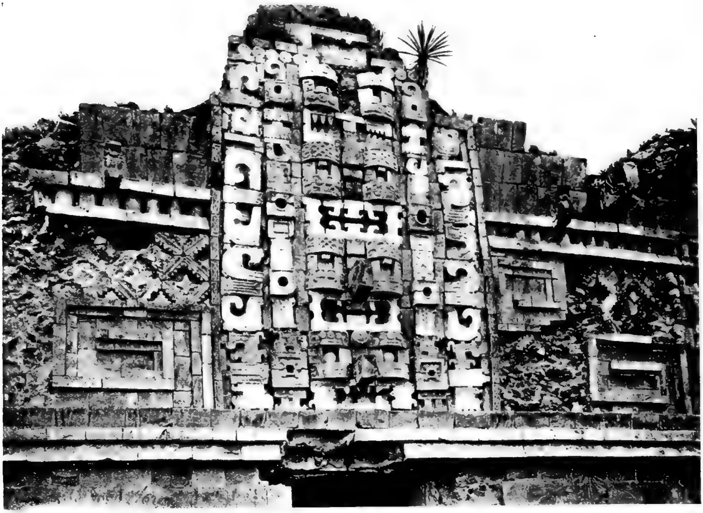
THE TEMPLE OF THE WARRIORS, RECONSTRUCTED BY PROF. K. CONANT. AFTER MORRIS.

Mask of Green Stone, Totonac (?) Culture, Near Teayo, Vera Cruz

The Sculpture of Pre-Columbian Central America

THE sculpture of Central America expresses in a more subtle and varied form the quality of impersonality noticeable in the architecture. The arts were created by nameless craftsmen to enrich their tribal ceremony, and were not expressions of the individual as they are today. Thus we see the Central American arts as a communal production, not the aesthetic reactions of a number of individual artists. Whereas the major buildings were the foci of the highly ceremonialized group religion, sculpture had a more diffuse function. Not only did it adorn the temples and explain their purpose, but also it depicted the god honored within the shrine. Plastic forms were also utilized in the creation of incense burners and other temple furniture. Sculpture had its place in the life of the individual, who fashioned from various substances his household gods and votive offerings. Again, images of people and animals were sometimes made to put into graves as equipment for the next world. If the plastic arts of the Central Americans were not entirely religious, their inspiration, at least, must have originated in ritualistic necessity, to judge from the all-permeating effect of religion on tribal life.

This religious domination makes Central American art seem to us cold, unsympathetic, and confused. Accustomed as we are to completely untrammeled artistic forms and to the glorification of the individual, it is hard for us to conceive how an art could be so imprisoned by ritual. Yet if we think back to the slow emergence of European art from the formulae of religious teaching, Central American sculpture becomes more conceivable. Its lack of emotional appeal is a question of racial interest. The Central Americans, to judge from their art, considered awe the proper emotional relation between the worshipper and his god. If European art had followed the Old Testament conceptions of religion instead of the New, the artistic forms of Europe and

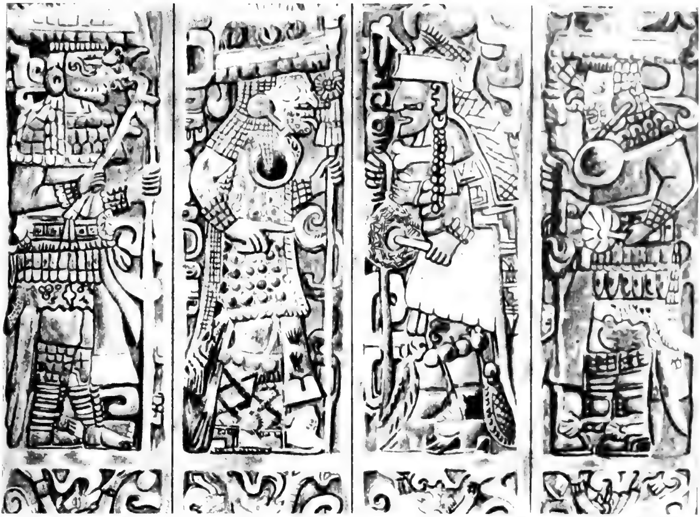


"HOUSE OF THE NUNS," AT UXMAL, YUCATAN, MEXICO

Late Maya period. Detail of the inner façade. Note the conventionalization of the superimposed serpent masks. Here religious symbolism has all but obscured the direct visual image, but there is complete mastery of design. After Holmes, 1915

CENTRAL VERA CRUZ SCULPTURE

In this carving of a wild turkey, the requirements of design are met, although the presentation is naturalistic. To represent it more dramatically, the figure is shown base upward



TEMPLE
OF THE CHACMOOL,
CHICHEN ITZA,
YUCATAN

Period of Mexican influence. These pilaster figures represent a stage midway between the complete religious symbolism (page 36, upper) of the late Maya and the more naturalistic treatment of the Nahua peoples. After Morris, Charlot, and Morris, 1931

CLAY TIGER FROM
OAXACA, MEXICO

Zapotec culture. A tiger god is represented by this clay figure. The attributes of divinity detract little from the lively realism of the figure proper which has been humanized to some extent

Central America might have produced a very similar emotional effect.

Another conflict between the modern observer and ancient American art is the variation in the ethnic ideal of beauty. Consequently, it is well to remember that the Central Americans were reproducing their own racial type.

The confused quality of the art arises from two factors, the presentation of the attributes and symbols of the various gods and the extreme fascination which complicated design held for the Central American. After all, if we examined medieval painting according to its original purpose instead of from our modern technical and aesthetic point of view, we would be infinitely bewildered trying to understand the attributes of the various individuals and the exact significance of the scene. Furthermore, simplicity or complexity in plastic design veers from one extreme to the other in the history of European art, so that Central American art cannot be justly dismissed by us on the ground of complexity alone. Therefore, if we discount our racial and emotional prejudices, aroused all too quickly by the unfamiliar, we find in Central American sculpture a competent and versatile art, well adapted to the portrayal of human beings, as well as the relationship between them and their gods.

GUERRERO, MEXICO

Unknown culture. This head of a monkey in black stone presents a happy balance between design and reproduction of a living form.

This sculpture is known to us chiefly by examples in stone and clay. Because of their perishability, few carvings in wood have been found, and shell, owing to its size, was used only for the making of ornaments. The carving of semi-precious stones like jade we shall defer to a later article on jewelry.

The earliest sculptures found are small figurines of clay. Their evolution can be traced fairly accurately through ascending stages wherein experiment and variety alternate with conventionalization arising from the attainment of temporarily satisfactory forms. The human form engaged the attention of these

early sculptors and there was a sustained effort to give the little figurines vitality by countless experiments in depicting the features. Owing to the difficulty of supporting strips of wet clay, arms and legs had to be disposed in more or less passive positions so that little action could ever be shown. Usually there is an underlying stylistic unity between the plastic product of each tribe, but occasionally individual expression obtrudes.

In the early culture groups clay sculpture was the dominating artistic medium, and, seemingly, the religion in those days must have been a simple anthropomorphism. With the rise of civilization the art was transformed to meet the requirements of religion, and the clay sculpture was no longer a dominant plastic medium. The development of a pantheon composed of different divinities atrophied the simple naturalism of the earlier art, and the invention of the clay mould made it possible to cast myriads of figures scrupulously defined by their attributes. Thus the craftsman tended to abandon this mechanical reproduction of divinities and utilize stone as a medium of expression, although he occasionally worked in clay with the most harmonious results. Conceivably, the increased specialization of individual activity in a developed civilization allowed men the opportunity to dedicate themselves to religious art, and to utilize materials like stone, which required time to shape.

OAXACA, MEXICO
Zapotec culture. This clay figure in the Oaxaca Museum is a striking example of Central American art, when allowed to express itself without religious symbolism. Photograph by Miguel Covarrubias

We know on archaeological grounds that stone sculpture developed later than clay in the Maya and the Mexican regions. While it began like the clay plastic, in the round, it took a somewhat different course. Where clay could be readily shaped, stone had to be laboriously pecked and ground into the desired form. On the basis of the earliest stone carvings recovered from Central American sites, there seems to have been no inheritance

COPAN, HONDURAS

Early Maya culture. One of the best examples of Maya sculpture is this magnificent limestone head in the Peabody Museum. Compare it with the racial types shown on pages 35 and 39. This photograph and that on the opposite page are by Dr. Clarence Kennedy

COPAN, HONDURAS

Early Maya culture. This conventionalized serpent head, also in the Peabody Museum, expresses vividly the ceremonial preoccupation of the Central American sculptors, which all but extinguished their extraordinary naturalistic gifts, as exemplified on the opposite page

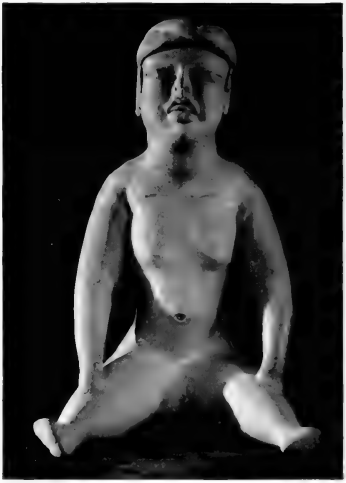
CUERNAVACA, MORELOS
Gualupita I culture. The genesis of the sculptor's art lay in the development of clay figurines like this in the Bourgeois collection in Mexico

from a former wood-carver's technique of which such strong traces exist in the sculpture of the archaic Greeks and ancient Egyptians. Wood-carving, on the contrary, appears to have followed in the path of the stone-work. Such a condition could well arise from the absence of adequate metal cutting tools, which so hampered the Central American sculptor.

It is perhaps owing to this circumstance that we note one of the most striking differences between Egypto-Grecian and Central American carving. The insistence in Old World art on anatomy would result from *hewing* out the rough outline of the figure, but the Central American preoccupation with external contour would arise from pecking and smoothing down the resistant stone surfaces. Probably the fleshy physical type of the Central American, in contrast to the muscular and bony European, also contributed to this divergence in presentation.

Once the Central American sculptors had mastered their material sufficiently to fulfill their conceptions of gods, men, and animals, they began to develop the various applications of sculpture and also to establish regional styles. Even as in architecture, there is discernible the cleavage between the gentle Maya and the fierce Highland tribes like the Nahuas and the Zapotecs.

Maya sculpture in stone is chiefly to be found enriching buildings or composing those great monoliths on which the priests caused to be inscribed the ceremonial pattern of their calendar. But scarcely a specimen exists of complete sculpture in the round, such as might be enthroned on the central altar of a temple to symbolize a god.



CUERNAVACA, MORELOS
Gualupita II culture. This clay figure represents an advance over the crude work of the preceding period. It is but a short step from this figure to the skilful presentation on page 39

The most impressive sculpture comes from Copan, Honduras, where exquisitely carved figures ornamented an architecture that, compared to other Maya cities, was inferior. Great skill was shown in bringing out the soft outlines of human faces, and, in the depiction of bodies, real anatomical skill was displayed. Grotesque beings were conceived with equal imagination and artistry. The great stone blocks of the stelae or time markers also presented majestic figures, carved in such deep relief that only the back of the block, containing the inscription, disqualified them from being sculpture in the round. To the north at Quirigua this art reached its zenith in gigantic stelae, twenty-five feet high, and in those fantastic bowlders, ornamented and reornamented into an essence of ceremonial involution.

PUEBLA, MEXICO
Unknown culture. This simple and vigorous presentation of a Highland face is characteristic of Nahua stonework. The eyes were probably inlaid with shell and obsidian

TEOTIHUACAN, MEXICO
Teotihuacan culture. This crude figure more than ten feet high represents an early stage in stone carving, which seems not to have been developed until long after modeling in clay

To the west, across the lowlands of Guatemala, is another style of Maya sculpture, that of the cities of the Usumacintla River. Here, at Yaxchilan and Piedras Negras lintels of hard zapote wood or of limestone were adorned by scenes in low relief. Stelae, too, were decorated in the same manner, and, although some of the relief is very deep, nowhere does it approach sculpture in the round. The finest examples of this school come from downstream, at Palenque. So low is the relief and so firm the line, that the sculpture almost enters into the realm of drawing and painting. Especially interesting in this Usumacintla art is the naturalistic treatment of the figures which are framed by the hieroglyphic text.

To the north, in Yucatan, the sculptures are largely reduced to theological abstractions, wherein the gods are depicted by a harmonious disposal of their

SEIBAL,
PETEN DISTRICT,
GUATEMALA

Maya culture. This detail from a stone time-marker is a magnificent example of Maya low relief carving. Note the combination of naturalism in the figure proper with the pure design of the disposal of the headdress and the hieroglyphs. Especially graceful are the headdress and its pendant plumes. After Maler 1908

VALLEY
OF MEXICO,
AZTEC CULTURE

This colossal head of the Goddess Coyolxauhqui in the Mexican National Museum is a masterpiece of Highland art. Compare the simple strength of this goddess, depicted as dead, with the softer elaboration of the Maya carving above

PIEDRAS NEGRAS, PETEN DISTRICT, GUATEMALA

Maya culture. One of the loveliest Maya treatments of life forms is this detail from a door lintel. Comparing it with the relief on the opposite page, one can see the difficulty in using modern European aesthetics to choose the best examples of an art based on totally different canons. Photograph by Dr. Clarence Kennedy

PANTALEON, GUATEMALA

Pipil (?) culture. This detail from a massive carving seems to represent a blending of Maya artistic formulae with the rugged strength of the Highland sculpture. Little is known of the ethnic affiliations of this distinctive school of stone carving

COSTA RICA
Guetar culture. This almost life-size stone figure comes from one of the cultures peripheral to the great Central American civilizations. It has a crude vigor, unobscured by the detail of religious symbolism

attributes. Such treatment precludes an appreciation of this carving as true sculpture, since it is, in reality, pure design. With the intrusion of the Mexicans and the rise of Chichen Itza, naturalistic reliefs again found favor, but they also had a strong theological flavor in their involvedornament.

Bordering on the Maya area to the south in Costa Rica and Nicaragua is a sculpture that represents a stylistic midpoint between the civilized conceptions of the Maya and the somewhat fumbling naturalism of the early cultures. Although probably contemporaneous with the best art of the Maya, it shows the archaism of provincial districts. There is, however, a rugged boldness about the major sculptures that establishes them as highly significant forms.

The sculpture of the Mexican Highland at the outset seems to have fallen under rigid theological control. The sculptures at San Juan Teotihuacan and the grotesque divinities of the later Aztecs, reflect the elements of pure design arising from the theological use of form. Yet occasionally one finds superb naturalistic treatment of divine subjects. Nowhere on the Central Plateau does that balance obtain between the intrinsic beauty of natural forms and the harmonious design of theological conception obtain as in the Maya sculptures of Copan and the Usumacintla region. However, the art of this people freshly endowed with the paraphernalia of civilization, has an undoubted strength and vigor that one does not feel in the gradual unfolding of the older and softer Maya civilization.

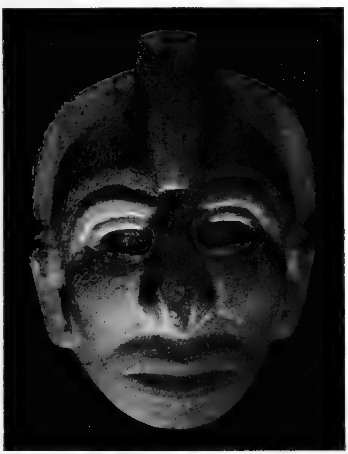
This conflict in Aztec art between the grotesque conventionalization of religious dogma and the naturalism arising from increased skill in portraying human forms may be seen reduced to its essential constituents in the arts of the Zapotec and the Totonac. The Zapotec of Oaxaca practised an extremely formalized art best exemplified in their clay funerary urns. In these specimens ritual is apparent in every line. Clay models were used to build up the ornaments and attributes of the divinities portrayed. Human or animal forms were used as a terrifying background for the addition of ceremonial features. Yet excellent naturalistic sculptures occur scattered infrequently through this art.

Among the Totonac of Vera Cruz we find the reverse, that the conventionalization of religious formulae is subordinated to a rich portrayal of the human form.

Whenever conventionalization is deemed necessary, it is concentrated on some object like a ceremonial yoke, but it is nowhere used to throttle a naturalistic expression. Extremely entertaining are the clay "laughing heads," which grin with a blissful good humor. A number of the heads from the Totonac region were shown with oblique eyes, and created the belief in some quarters that this was Chinese influence. Since the American Indian is of Mongoloid stock, it is not surprising that such traits as the epicanthic fold should be reproduced in the sculpture, but it by no means implies that Chinese art had any connection with Central American.

TEMPORAL, VERA CRUZ, MEXICO
Huaxtec culture. This seated female figure is a survival of the most primitive art in clay

From the point of view of the European, these east coast Mexican forms are the most satisfying of all the various Central American sculptures, since there is a minimum of theological grotesqueness. Closely connected with this Totonac art is that of the Huaxtecs at the north of Vera Cruz. Although Maya-speaking, their sculpture shows no artistic influence from the parent stock and is noteworthy in its appreciation of youth.



GUIAROO, OAXACA, MEXICO
Zapotec (?) culture. The rugged racial type of the Mexican Highlands is shown vividly by this small stone head

An exquisite group of sculptures comes from a strip of territory that runs from coast to coast between the lands of the Aztecs and the Zapotecs. Conjecture might attribute these marvellous carvings to the Olmec, who appear in the dim background of mythological history. It is a perplexing paradox that the creators of the beautiful heads and ornaments from this area, which were traded far and wide, must rest in anonymity, unless further research can define them. Much of the sculpture belongs to the lapidary's art.

Another important style of sculpture comes from the Pacific slopes of Guatemala and expresses a fusion of Nahua vigor and Maya mastery of ritualistic design. This plastic style suggests a sudden genesis, rather than the slow evolution of a self-contained tribal art.

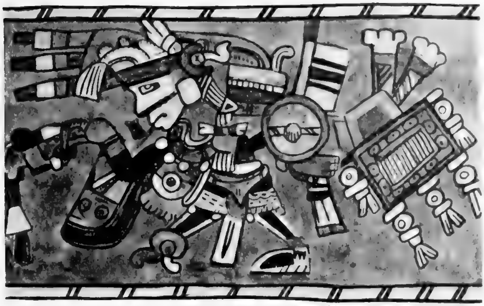
Finally, the rich clay plastic of Western Mexico gives us an idea of the utmost

development of a people who were subjected neither to the discipline of complicated ritual nor to the stimulation of a highly organized religion. While there is great variety in subject and attitudes, the characteristic one would expect from an art in the hands of the people, there is none of the finish of the Central American arts under hierarchical control. If these western Mexican sculptures are basically religious and intended for use as mortuary offerings, they are nevertheless worked out by lay methods. They are in reality survivals of an older aesthetic system.

However unified the purpose of Central American sculpture, it is not the product of a single people and should not be so considered. It is the product of a number of tribal groups, of different language and physical types, striving to glorify their religion, according to their various abilities. Yet there is, none the less, a generic resemblance in the sculpture as a whole, which lies in the absence of those sensual and emotional features that characterize our own. It is not to be expected that people of one race can derive from the art of another the same psychological reaction, particularly if it is religious. However, the detached and impersonal repose of the Central American sculptures has a soothing effect in this modern era where intensely independent individuals strive to perpetuate their personalities in the face of mass production. While there is conflict in Central American sculptures between the freedom necessary for naturalism and the conventionalization dictated by theology, it is a struggle of technique. The creators of the sculptures were harmonizing their tribal life with the rhythms of nature. They expressed their gratitude for divine favors through the skilled anonymity of their craftsmen, and their works registered complete content without a sign of the fickle protest in our modern art.

QUIRIGUA, GUATEMALA, MAYA CULTURE. THIS STELE OR TIME-MARKER IS SOME 25 FEET HIGH AND SHOWS THE CEREMONIAL ART OF THE MAYA AT ITS BEST
AFTER MAUDSLAY, 1889–1902

WESTERN MEXICO. THESE CLAY FIGURES EXEMPLIFY THE VITALITY AND HUMOR OF A FOLK ART UNAFFECTED BY REQUIREMENTS OF RITUAL



Fresco, Tizatlan, Tlaxcala, Mexico. After Caso, 1927

The Art of Painting in Pre-Columbian Central America

CENTRAL American painting does not show the same masterly control over subject and material that is so evident in the architecture and sculpture. Perhaps this inferiority may be due to the rarity of examples. Frescos and deerskin or paper manuscripts are extremely perishable, so that few specimens have survived the action of the weather or the destructive fanaticism of the Spanish priesthood. Much more probably, however, the ritualistic restrictions which controlled the architecture and sculpture have limited painting even more, for this art was confined to a didactic or explanatory supplement to the religious symbolism expressed by the stone carving, or else was used for simple narrative purposes in connection with the historical annals.

The term "painting" we are using in the common sense of the word, to mean a picture, not the mere laying on of colors. Hence we shall not consider the designs on pottery vessels nor touch on the coloring of sculpture, which was a universal Central American practice. On the border line of this subject are the low reliefs of Chichen Itza and the Usumacintla River sites. These sculptured friezes were coated and corrected with plaster before they were painted, but they do not really fall within the scope of *painting and draughtsmanship*. Therefore we shall confine ourselves to the examples of frescos, manuscripts, and vases which depict actual scenes, in distinction to designs.

Few frescos have survived, since those natural agencies which have caused whole buildings to crumble, attack first the paintings on their walls. The surviving examples display colors such as red, blue, yellow, and green, obtained from ochreous earths and sometimes from vegetable dyes. Occasionally scarlet cochineal, obtained from insects, was employed. The earliest examples known to us are from San Juan Teotihuacan in the Highlands of Mexico, where the painter, despite

Caracol,
Chichen Itza,
Yucatan

This circular astronomical observatory is shown partly restored by the Carnegie Institution of Washington. The disintegration by natural forces that ruins massive buildings like this, offers scant chance of survival to perishable materials like frescos and manuscripts. The wonder of Central American painting is that any examples survived at all

This limestone low relief from Tabasco illustrates the transition between drawing and sculpture. The Central American never could suggest by his brush the delicate contours he achieved in modeling

The painter of the vase from Guatemala, a detail of which is shown below, lacked only an accurate knowledge of perspective to equal the masterly result of the sculptor whose work is shown above. After Gordon, 1928

his rude drawing, has caught in lively terms a ceremonial scene. Especially noteworthy is a conventionalized design combining various fruits and plants.

Most of the frescos presumably date from the time immediately preceding the Conquest, and come from Yucatan where the rugged stone architecture resisted the elements, and in consequence preserved the fragile paintings within the rooms of the buildings. A number of the subjects seem to be secular. At the Temple of the Warriors, in Chichen Itza, two animated scenes were reconstructed by Ann Axtell Morris from the fallen blocks of the temple vault. In one a seaside village is shown, and in the other the defeat of a foray by marauding strangers. There is no real grasp of foreshortening, but the arrangement of the figures suggests a dawning knowledge of perspective. In the Temple of the Tigers at the same site there is a fresco depicting another attack, and in this case some rather successful attempts at foreshortening have been achieved. At other sites like Chacmultun scenes have been attempted but the draughtsmanship is crude.

Religious Frescos

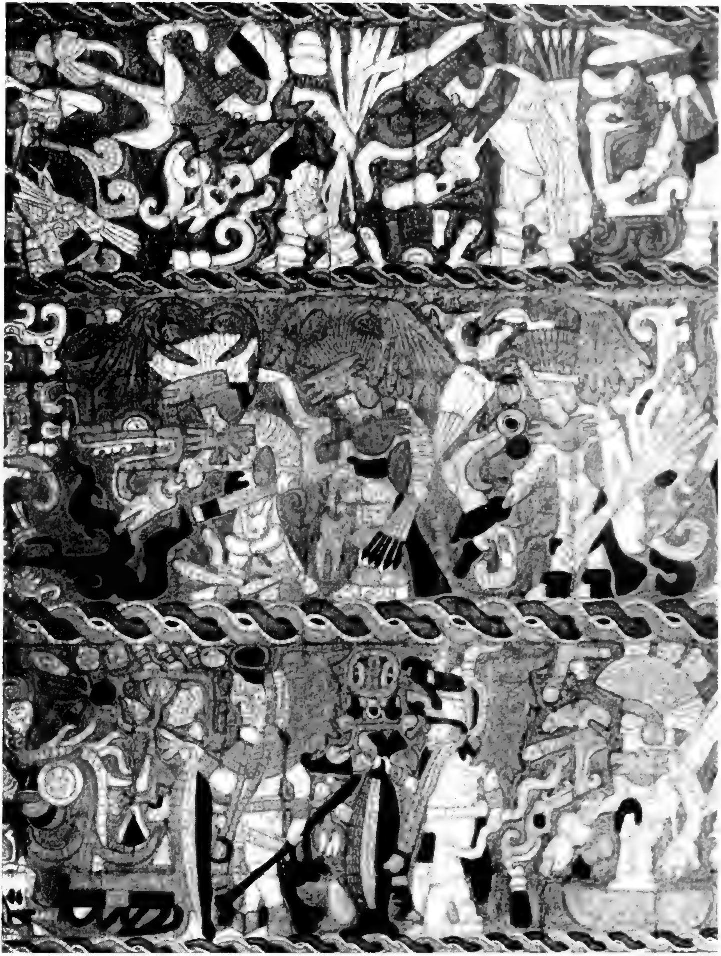
There are a number of purely religious frescos, without the secular element introduced by the presence of human beings. The most celebrated are found at Santa Rita in northern British Honduras, and at Tuloom on the east coast of Yucatan. In this group the element of design is dominant, and the divinities are arranged according to the dictates of ceremonial pattern. Curiously enough, although found in Maya territory, these frescos have strong affinities in subject and style to the paintings at Mitla in distant Oaxaca.

The Mitla frescos are entirely ceremonial, being composed of divinities and their attributes, and they are closely related to the codices or ritualistic books of that area. Other Oaxacan examples are extremely rare, and in Central Mexico, save for the frescos at Teotihuacan already mentioned, the painted altars at Tizatlan, near Tlaxcala, alone are worth consideration. These designs are composed in brilliant colors, but the content is purely ritualistic and ceremonial. Like the Mitla frescos, the draughtsmanship is closely related to that of the manuscripts.

Illuminated Manuscripts

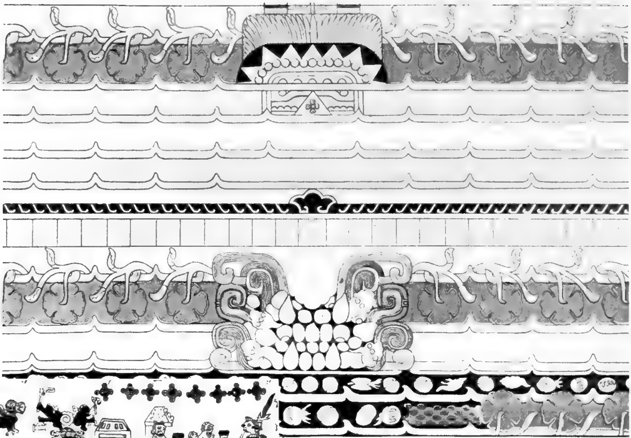
By one of those constant paradoxes in Central America, codices abound where frescos are few, and vice-versa. Thus on the Mexican Highlands there are many illuminated manuscripts, but, as we have seen, few frescos have survived. On the other hand, in the Maya country, the source of most of our knowledge of fresco painting, only three books have been preserved. For a knowledge of draughtsmanship, the manuscripts are a most valuable source of information. They include ritualistic and divinatory manuals, historical annals, tribute rolls, maps, and the like. Thus in the rendition of the subjects chosen, artistic considerations were always secondary to the needs of exposition.

Middle American writing was at a relatively primitive stage. It was ideographic and phonetic, the principle being that of our modern rebus. There was, however, no means of conjugating verbs or declining nouns. Consequently action had to be expressed by pictures. It is quite probable that long recitations learned by rote and passed on from generation to generation supplemented the picture writings which served as a mnemonic aid. A great many of these documents gave calendric and astronomical calculations, and the inscriptions are largely composed of the names and numbers of the various dates, the pictures of the gods presiding over the various days, and the ceremonies associated with them.

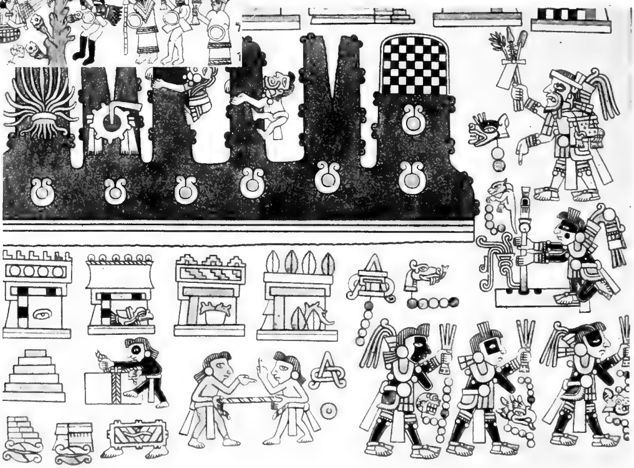


Painted Relief from Chichen Itza

This carved wall from the lower chamber, Jaguar Temple, was covered with plaster and then painted. A procession of priests and warriors converges on an altar in honor of their god Quetzalcoatl, the Feathered Serpent. The warriors carry spears and spear-throwers, and the two priests have feathered robes in their hands

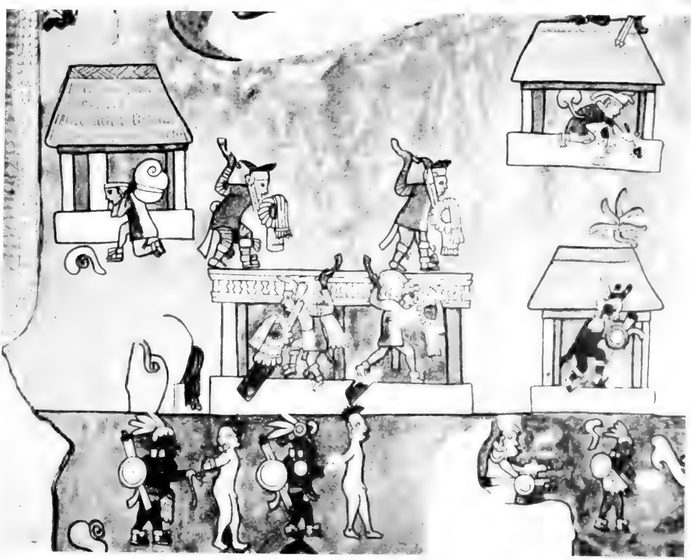


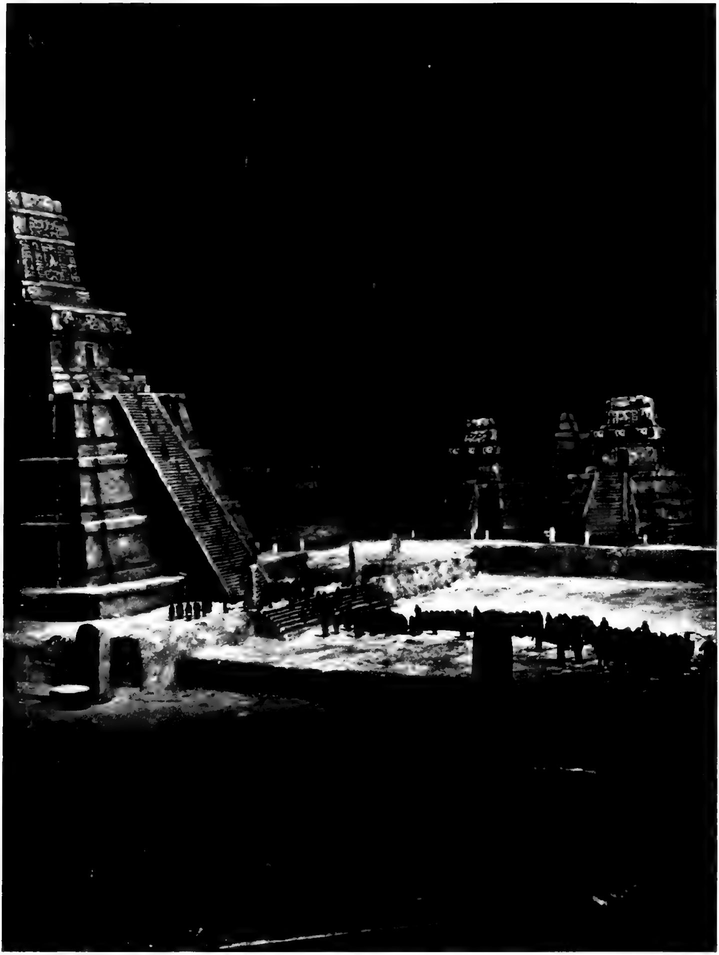
Ritualistic uses of painting. The upper picture, an altar at Teotihuacan (Gamio, 1922), shows religious formulae reduced to pure design. The middle picture from the Codex Florentino describes a ceremony in which people dressed as birds or gods participate. At the bottom is a scene from the Vienna Codex after Humboldt, 1814. The content is partly ceremonial and partly historic



Descriptive uses of painting include this woodland scene from the Temple of the Warriors at Chichen Itza. The panther in the tree suggests that the artist cared more about defining his genera than drawing them naturally. After Maudslay, 1889-1902

Detail from a battle scene, Temple of the Warriors, Chichen Itza, shows considerable animation in the house to house fighting and the captives being led off for sacrifice by the black-painted priests. After Morris, Charlot and Morris, 1931

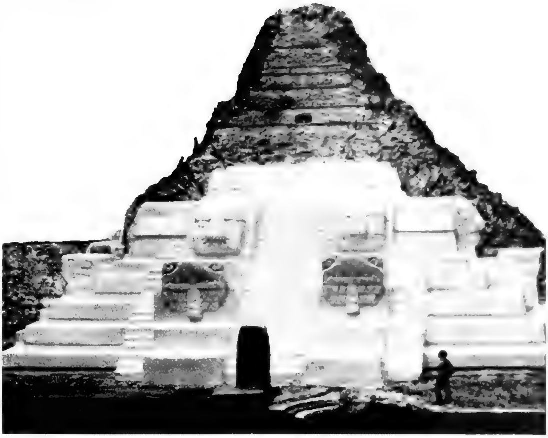




Tikal

This dramatic model constructed by Herbert Maier aided by H. Marchand, and H. B. Wright for the Buffalo Museum shows a typical early Maya ceremonial center. The jungle has wreaked havoc with the site so that now little except the architecture remains of the achievements of its builders. Thus the incomplete patchwork comprising present knowledge of Central America utilizes scraps from many sources

Perishable remains like this plaster temple at Uaxactun, Peten District, Guatemala, are sometimes miraculously preserved. This model cross-section shows how a later building sheathed the earlier structure and protected it (See p. 21)



This fresco from Teotihuacan, perhaps the earliest in this series, was saved in the same way. Men and women offer gifts to the statues of two gods at either side of the picture. On the altars before them burn sacred fires. After Gamio, 1922

The three Maya books fall into this last category. As the Maya had developed an extremely conventionalized way of depicting word symbols, the pages, from an artistic point of view, do not compare with the Highland documents. Among the latter the manuscripts assignable to the Mixtec civilization are especially handsome. The day signs and the representations of the divinities are carefully, one might say arduously, drawn. Proportions are based upon the ritualistic importance of the details shown rather than their anatomical symmetry. Colors are used not only to reproduce natural tones but also to define the object ceremonially, since colors had a strong ritualistic significance in Central American religion. Permeating all the symbols, and their distribution on the page, is design, which follows closely in the train of the order implicit in ritual.

Aztec Painting

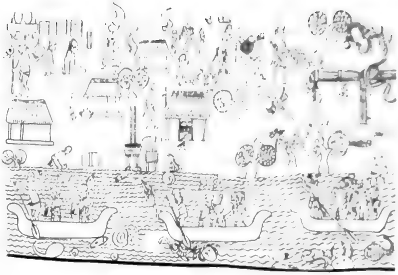
In comparison to the Mixtec documents, the painting in Aztec manuscripts seems barbaric, but because it is less confined by ceremonial restrictions it has a freshness rather engaging to our eyes. Furthermore, the Aztec system of writing was incorporated into the Spanish colonial administration, both as a method for keeping legal records pertaining to Indian affairs and as a means for disseminating Christianity among the natives. It is, therefore, possible to see in a number of drawings the transition from a purely Indian to quasi-European style of draughtsmanship.

In the purely ceremonial documents, like the *tonalamatl* or sacred almanac, there was a close connection with the extremely stylized documents of the south, but there is more immediate interest to the casual reader in the annals. These follow two forms. One is in the nature of a map, where the events are set forth much as are localities. A knowledge of the symbols defining personages and tribes does not explain the action entirely, so that manuscripts of this type must have been supplements to oral tradition. The other class is more self-contained. The symbols for the years were set down successively, and lines connect the various events pictured with the year glyphs. Some of these records, like the *Annals of 1576*, were kept well into Colonial times, but the text gradually shifted from picture-writing to Nahuatl words transliterated into Spanish characters.

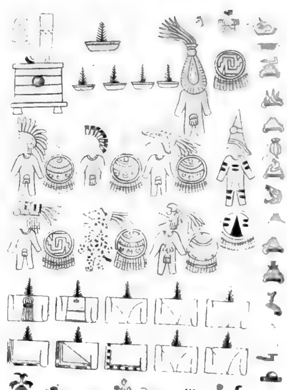
Another category of documents is composed of the tribute rolls, land grants, and similar administrative records. The Aztecs kept careful account of the toll to be exacted from the towns they conquered. Pictures of the objects with symbols for the quantity are set down together with the hieroglyphs designating the tributary pueblos. Other records show the land held by individuals and the rent payable, and, as these records were retained in colonial times, there is often a gloss in European characters, describing in Spanish or Nahuatl the significance of the document. A few colonial manuscripts exist wherein the symbols were rearranged into a sort of phonetic writing, suitable to record prayers. The Spanish priests broke down the ideographs into a system of actual writing, but the greater serviceability of Spanish characters caused this attempt soon to be abandoned.

Codex Florentino

The most diverting document from Central America is the Codex Florentino, a collection of pictures illustrating Father Bernardino Sahagun's exhaustive work, *A General History of the Things of New Spain*, written about 1565. These drawings depict every detail of Aztec social life and religion, not to speak of delightful excursions into natural history. The draughtsmanship suggests the phrase

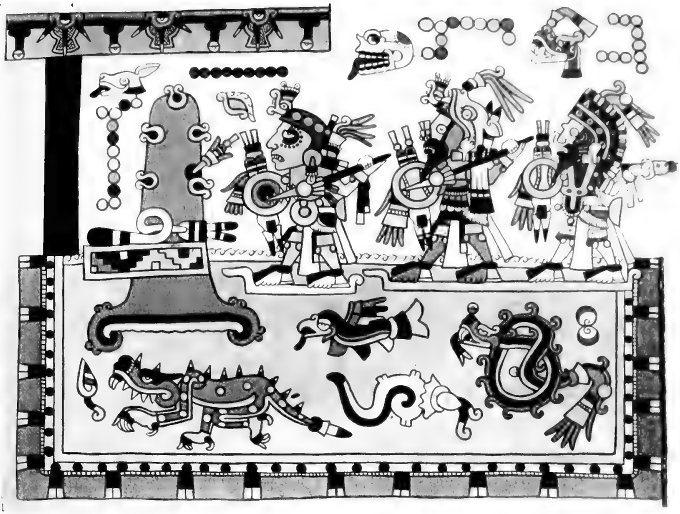


Mexican narrative painting. Successively presented are the Conquests of Montezuma II (*Codex Telleriano-Remensis*), a seashore in Yucatan (*Temple of the Warriors*), the meeting of Cortes and Montezuma (*Lienzo de Tlaxcala*), the migration of the Nahua tribes (*Codex Boturini*), an Aztec ceremony, (*Codex Borbonicus*), and an Aztec tribute roll (*Tribute Roll of Montezuma*)

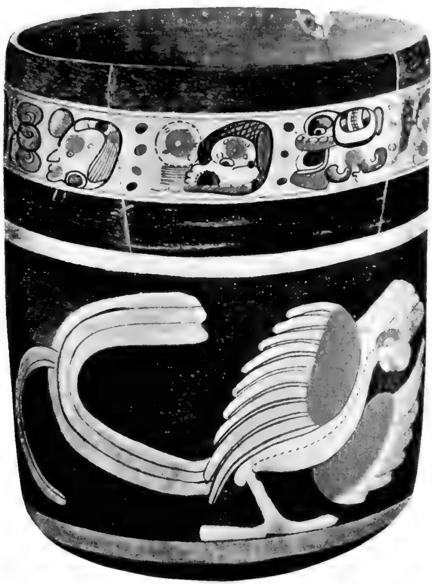


This mortuary bowl from Uaxactun shows great ease and freedom in drawing. The hole in the center of the vessel was made to kill the pot, so that it could pass with its owner to the next world. After Smith, 1932

The detail shown below from another Maya vase commemorates the meeting between a Maya chief (at the left) and a noble stranger. The features are accentuated to express racial differences. The glyphs doubtless give explanatory details. After Dieseldorff, 1904



This painting from a Mixtec history, the Codex Nuttall, involves a group of warriors in canoes, who are attacking a town on an island in a lake. Note the ingeniously stylized wild life which inhabits the water. After Joyce, 1927



No such schematic drawings as shown above mar this Maya vase from Copan, which represents a quetzal or trogon, the sacred bird of the Maya. After Gordon, 1928

"old wine in new bottles," since despite the influence of European methods of drawing, the content and psychology are Aztec.

The preceding pages have outlined the two principal sources for Central American painting, the frescos and the manuscripts. While the frescos show a certain fresh ability in presentation, the manuscripts on the whole exhibit the lifelessness that one would expect from the standardized repetition of signs and symbols already defined by ritual. The draughtsmanship does not equal the sculpture and the architecture. Yet there is the inevitable exception to every generalization, and this is to be found in a small group of Maya vases, where a lively and subtle style of drawing is to be found.

Human figures, naturalistically presented, are extremely rare in Central American pottery decoration, and are confined almost exclusively to the Maya region. The style commences at Copan in a vigorous shorthand and finally blossoms into its fullest flower in the Chama region of Guatemala, although there seems to have been a sub-center in the Peten district of the same country.

The scenes are apparently purely descriptive. A notable receiving an embassy from another tribe is depicted on one vase. On another a high personage is borne on a litter, and a third vessel is decorated by a scene wherein a chief seated on a throne holds a levee. The racial types are exaggerated, but the positions of the body are as graceful in carriage as they are harmonious in design. The strong, sure outlines recall the best of the low reliefs from the Usumacintla River region, and it is apparent that the same school of draughtsmanship which inspired the vase painting controlled also the outlines of the reliefs. When we remember that sculpture was always painted in Central America, it will be seen that here painting and sculpture blend. In the Maya vase painting we have at last found an approximation to the beauties of the stone carving.

The art of painting in Central America exists for us by implication, much as does the delineative art of the ancient Greeks for which vase painting and literary description are the principal sources since the paintings themselves have disappeared.

The frescos are not really representative, because either, as in the case of the Teotihuacan examples, they came from a primitive civilization, or, as in the Yucatan, they were the product of a decadent one. In the codices, the draughtsman's skill, because of delineative and ritualistic conventions, had no opportunity to express itself save in design. Only in Mayan vase painting do we find that the painters give indications of a skill equal to that of the architects and the sculptors.

Maya vase, from Nebaj, Guatemala. After Gordon 1928

The Crafts of Pre-Columbian Central America

MANY of the crafts of ancient Central America have persisted to the present day in spite of the transformations which the Spanish Colonial Empire and modern industry have wrought on the native civilizations. The major arts of the ancient peoples now exist more as an heirloom than a useful heritage. The modern artists from the Central American republics have recently utilized aboriginal themes, but between them and their source material stretch four hundred years of European artistic inspiration. In the crafts, however, there are connections, ofttimes tenuous to be sure, with the aboriginal industries. Sometimes only the technique survives, and the subject matter is completely Spanish Colonial or modern Republican. None the less, it is in the crafts that we feel most strongly the influence of the Indian past.

The applied arts of the ancient civilizations embodied many of those characteristics noted in architecture, sculpture, and painting. The same religious purpose that dominated the stone carving not only extended to ceremonial dress and temple paraphernalia, but even penetrated into secular possessions. Thus the elaborate decorative expression of ceremonial values influenced the craftsman as much as it did the creator of artistic masterpieces. Such a result, however, is natural, for there are no sharply drawn distinctions between the two spheres of action. Skilful workers were drafted to enhance the religious ceremonial, which gave the chief outlet for aesthetic expression. Wealth and social position, which make possible the private possession of fine things, were inextricably combined with the gradations of the religious hierarchy.

Surviving examples of these ancient arts must often take the place of selected masterpieces, for most of the perishable material has disappeared, owing to natural decay or to the willful destruction of war and conquest. Often the written descriptions of the Spanish Conquerors or the crabbed drawings in the native documents offer the sole testimony of remarkable craftsmanship in ancient Central America. Descriptions of the jewelry and pottery we shall reserve for succeeding chapters, since much of this material is wrought of imperishable substances and has survived in far greater quantities than examples of weaving, featherwork, wood carving, and the like.

Weaving was an important art in Central America, but few examples have resisted decay. To determine its degree of excellence we must rely on knowledge derived from other areas, where arid climates have preserved textiles and other perishable materials. The Basket Makers of the Southwestern United States, the earliest agriculturists discovered in that region, developed great skill in weaving cloths, sandals, and baskets, before they learned how to make pottery. Thus we can postulate with some confidence that weaving in the New World was well advanced on a very early cultural horizon. At the other extreme we find the magnificent textile art of ancient Peru, miraculously available to posterity, because the arid climate preserved thousands of burials, each enveloped in several lovely fabrics. That distinguished authority, Mr. M. D. C. Crawford, said of Peruvian weaving, "No single people we know ever invented and perfected so many forms of textiles," and again, "In tapestry Peru reached its highest textile development. The harmony of color, the beauty and the fastness of the dyes, and the perfection of

Costumes

The richness of Aztec costume deeply impressed the Spanish Conquistadores, but the contemporary drawings do scant justice to the originals. These illustrations by Keith Henderson for Prescott's *Conquest of Mexico* published by Henry Holt in 1922, recapture the splendor of the Aztec scene, thanks to the artist's study of native source material

This drawing of the Aztec ambassadors to Cortes shows the dress of high officials. Note the elaborate coiffure and the ornamental mantles. The feather fans further add to the splendor of the costumes

warriors how the imagination that governed gala [illegible] As this is a peace time occasion, they are carrying flowers and standards in the place of weapons. Cotton, skins, feathers, and paper were utilized in composing these outfits

Women's dress, as exemplified by these Totonac girls, was relatively simple, yet with a little tailoring these lovely fabrics would not be out of place as sports costumes today

spinning and weaving, place these fabrics in a class by themselves, not only as compared to other textiles of this land, but as regards those of any other people."

Although we have scant means of judging the relative merits of the fabrics of Central America and Peru on the basis of weaving technique, we can compare their designs. The Mexican tribute rolls list mantles in many patterns, and on the great Maya sculptures we see evidence of the most elaborately decorated vestments. These designs are by no means inferior to those adorning the textiles of Peru. If the actual weaving processes were less developed in Central America than in Peru, the decorative aspects must have been very nearly equal.

Enrichment of Fabrics

The greatest development of the Central American textile art lay in dress. Although the quality of the garments depended on the station of the wearer, the basic costume was the same for all classes. Men wore a breech clout and mantle, knotted at the neck, both made of cotton or maguey fiber. Women usually were clothed in a skirt and a long blouse, the *huipil* which is still worn in parts of Central America. Such costumes could be varied or enriched by the quality of the fabric or by its decoration of brocade, openwork patterns, or embroidery. Additional means of enriching the fabrics were provided by tie-dyeing, batik, and complete dyeing in colors made of various vegetable and animal substances like logwood or cochineal. Clay stamps were used to print designs either on the fabrics or on the skins of the wearers.

The accessories of dress called into play much cunning craftsmanship, since for ceremonial occasions and warfare dazzling costume was demanded. A conspicuous element of ceremonial dress involved the use of feathers. Sometimes the feathers were attached to a loosely woven fabric in such a way that they made an actual cloth, with the designs worked out in various colors. The plumage of different birds was also employed as a mosaic adorning shields and helmets. Long plumes of tropical birds furnished crests on headgear or formed part of the standards which picked warriors wore on their backs to distinguish various clan and tribal units.

Featherwork and Wood Carving

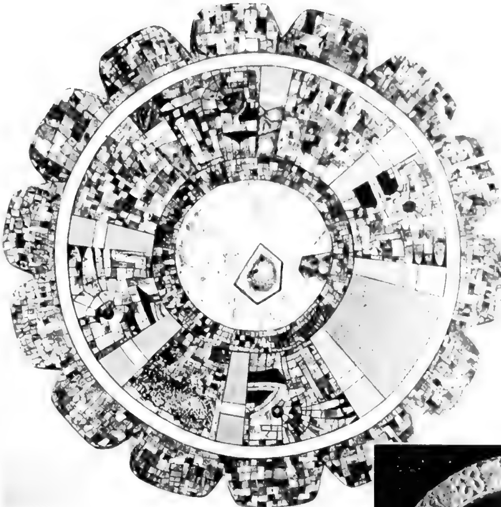
Today the finer types of weaving and featherwork have disappeared with the destruction of the ancient religion, and the adoption of European costumes for gala occasions. An attractive embroidery still lingers on the Highlands of Guatemala, although many European motives have entered the designs. The featherwork, too, has almost ceased to exist, but, during the Colonial and early Republican period in Mexico, a sort of landscape painting in feather inlay survived.

Wood carving, like weaving, would be difficult to appraise, had not a number of examples found their way to Europe as trophies of the Conquest. Other specimens have either been guarded as heirlooms, or discovered by chance in dry caves. Prof. M. H. Saville, in his *Wood Carvers' Art in Ancient Mexico*, has gathered together all the available information on this art. The most intricate work is represented on several atlatls or throwing sticks, which must have been reserved for state occasions. The same mastery of design which distinguishes the major works of art characterizes this carving. Wooden drums show equal artistic ability and the human and animal forms of several belong properly to the realm of sculpture. The construction of one type, the *teponaztli*, required considerable ability, for the sounding board consisted of two tongues of wood which were partly freed from the hollowed block of the drum and gave different notes. Although the tone of the drums varied considerably, the interval between the notes of each was always the same.

Mosaic Work

Masks of wood for religious purposes were frequently made, since the gods were im-

Turquoise mosaic mirror, Chichen Itza, Yucatan. The reflecting surface was probably made of a number of fragments of iron pyrites laid against the sandstone center. The elaborateness of the setting together with its discovery beneath an altar indicates that its use was ritualistic After Morris, Charlot and Morris, 1931



Right:—Obsidian mirror with gilded wooden frame Mexico. This exceedingly rare specimen was purchased in Europe and may well have been among the presents sent to Charles V by Cortes

Lacquer tray. These gay utensils were a characteristic product of Mexican Indians during the Colonial period, and in recent years their manufacture has been revived in various villages in western Mexico. It is probable that their origin is Pre-Columbian

Pages From a

The Codex Florentino consists of several hundred paintings by Aztec artists to illustrate Father Sahagun's great work on the Aztec civilization. The pictures shown here give an idea of the complexity of the civilization. Besides the divisions expressed by our nursery rhyme, "Rich man, poor man,—" there was a great variety of other trades and professions, some of which

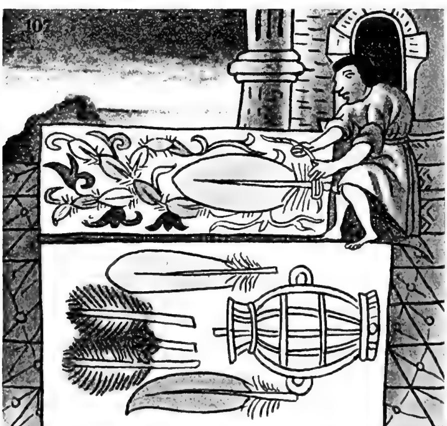
Rich Man

Poor Man

Beggar Man

Gold Worker

Thief



Feather Worker

Soldiers

Mexican Album

are shown at the bottom of these pages. Since the illustrations were intended for secular consumption, naïve vivacity (see "Bathers") replaces the usual ritualistic formality. Compare these drawings with those of Keith Henderson on pages 64-65, to see how faithfully that artist caught the native spirit, and to guide the eye in perceiving the subject matter which is depicted in this group

(2)

Chief

77

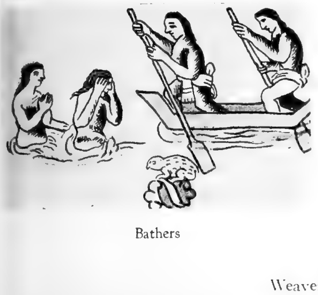
Merchant

76.

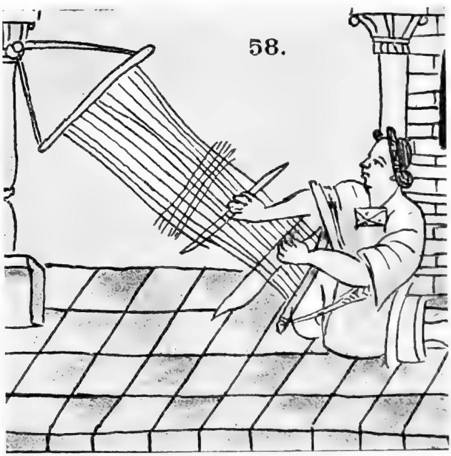
Lawyer

Women

Doctor



Bathers



Weaver

personated in a number of ceremonies. Warfare, too, created a function for the wood carver in providing helmets which frequently took the form of animal heads. Yet such work was really the base for another distinctive Mexican craft, mosaic work, for knowledge of which we are again indebted to the erudition of Professor Saville. Fragments of turquoise, jade, obsidian, and shell were inlaid with consummate skill, and this art was a favorite method of embellishing a multitude of implements and jewelry. One of the most extraordinary examples of the craft is a shield in the Museum of the American Indian, where a scene in low relief is carried out in turquoise mosaic. The temples at Mitla show an adaptation of this mosaic technique in the creation of decorative friezes. Today, however, little or nothing survives of this industry.

A craft much more widely practised was the cutting of shell. The demand for this easily manufactured substance was enormous. Few indeed were the New World peoples, however primitive and however distant from the coast, who did not barter for their quota. Shell most frequently was made into beads or pendants, and perhaps because of its almost universal use, seldom received the attention of the more skilful craftsmen. Yet conch shells were sometimes ground and carved into handsome trumpets, while some were covered with plaster and painted with ritualistic designs. A few engraved gorgets show how readily this material responded to a skilled craftsman, but such ornaments are rare. Evidence exists that the carapaces of turtles and armadillos were also worked in ancient times. Some very beautiful objects are made of tortoise shell, today, but it is problematical whether this can be called a legitimate survival, or is of European introduction. Far to the south, in Panama, there occur splendid bone carvings that are reminiscent of major sculptures. Mention should also be made of carved whale teeth in the same region, and carved jaguar fangs in the Maya country, a type of work which showed considerable ingenuity in adapting the design to the natural form.

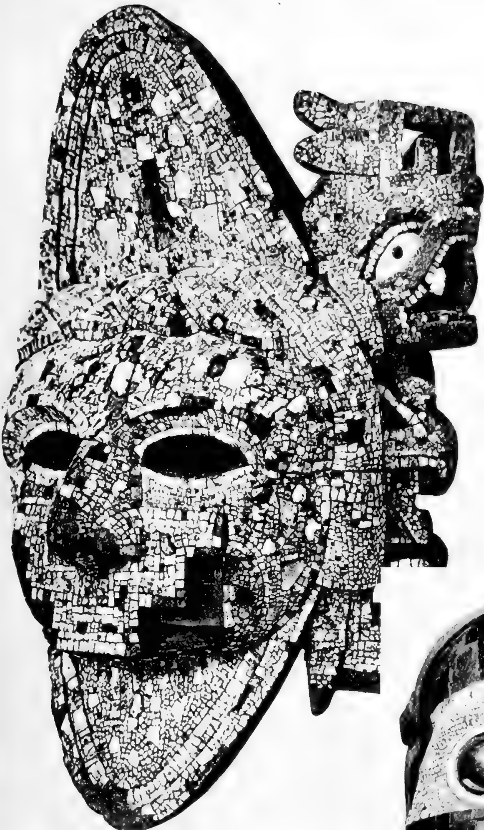
Horn and bone were substances perhaps too work-a-day for the highly skilled artisan. Needles, awls, flakers for stone tools, and many other household implements were made of bone, but seldom does one find a beautifully worked example. The most notable exceptions are the jaguar bones from the priestly tomb at Monte Alban. These were split and polished, and on their convex surfaces inscriptions of a ceremonial character were chased, with a minute precision worthy of the Japanese. The backgrounds of these patterns were picked out in turquoise mosaic. Engraved human femora, sometimes ornamented in mosaic, are grim reminders of the exigencies of Nahua religion.

Stone Artifacts

Work in stone we have considered in respect to architecture and sculpture, and shall describe again in connection with jewelry. Yet to manufacture the ordinary implements of everyday life required a consummate mastery of an obdurate material. To detach in a single effort the thin blades of obsidian used as razors and scalpels for ceremonial blood letting necessitated as skilful a coördination of strength and skill as did the patient flaking of the great leaf-shaped sacrificial knives. Some of the axes ground from hard stones like jade and serpentine are aesthetically satisfying in their useful symmetry. This same pride in craftsmanship, which was not unlike that of a medieval smith, seems to have dominated even the manufacture of an arrowhead every facet of which shows the skilled impress of the worker's hand.

Ancient Mirrors

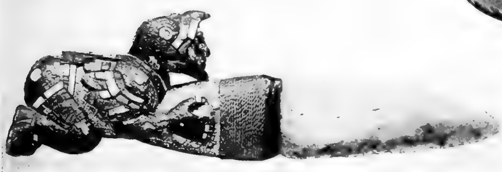
The manufacture of mirrors gives yet another aspect of Central American capability. There were in that region relatively few substances that could take a polish high enough to give a reflection. Glass and bronze were unknown, and copper never seems to



Mosaic

Mosaic working was one of the most elegant of Central American crafts, and color reproductions alone can give its true value. The wooden mask (taken like the two other illustrations on this page from Saville, 1922) was purchased from Cosimo de Medici for the Prehistoric and Ethnographic Museum in Rome, for two and one half francs. It must have been part of the loot from the conquest

Right:—This mosaic has as its matrix a human skull cut away in back to form a mask. It is one of the treasures of the British Museum. The lighter bands are turquoise and the darker, lignite



Left:—This sacrificial knife in the British Museum is a little more than a foot long. Turquoise, malachite, and variously colored shells compose the mosaic work which depicts an Eagle Knight

Featherwork is so extremely perishable that almost no Pre-Columbian examples survive. Under Spanish colonial influence, a sort of genre painting in feathers was developed which continued in Mexico until the middle of the last century. Examples of this feather painting in its degenerate state are shown at the left and on the opposite page. At the bottom of page 68 is shown a featherworker practising his craft, and from the pictures on pages 64 and 65 one can judge how important an adjunct to costume feathers were

This headdress (from Heger 1908) originally belonged to the ill-fated Montezuma and was sent by Cortes to the Emperor Charles V, who in turn gave it to his nephew Ferdinand II of Tyrol. Kept in Ferdinand's castle at Ambras, this unique headdress finally became part of the collections of the Natural History Museum in Vienna

Feather-Work

The patient selection of different colored feathers and the care in joining them, as exemplified by this picture, made during the last century, is a direct expression of the Indian heritage in Mexico. It is curious to see in comparing this and the feather painting opposite with the costumes on pages 64 and 65 how little the dress of the Indian has changed with the ages. Only the trousers and the hat distinguish these people of 1850 from their ancestors of three centuries and a half before

have been used for such a purpose. The inhabitants did, however, make mirrors of iron pyrites and obsidian. Iron pyrites sometimes occur in small nodules on which a plane surface could be ground, giving a very satisfactory reflection. Another type of mirror consisted of thin plates of pyrites, laid like a mosaic on a backing of pottery or stone. Few complete specimens are known, but there do exist a number of stone discs which may well have been backs for such mirrors. It is quite probable that the celebrated mosaic disc from Chichen Itza could have had a mosaic of iron pyrites in its center. A unique mirror in the American Museum of Natural History utilizes iron pyrites in their original slate matrix, the pyrites being polished as a surface and the slate carved as an ornamental back. The obsidian mirrors of Central Mexico are among the wonders of ancient technology, since even a modern lapidary, with his diamond drills and carborundum wheels has difficulty in grinding down this volcanic glass to the lustrous sheen of early times. Mirrors of both materials must have been very precious, and it is not surprising that they were used as much for divining purposes as to cater to the vanity of their owners.

The introduction of iron and steel tools has largely destroyed the ancient crafts of wood carving and stone work. Yet two very flourishing crafts survive, that may well have had a pre-Columbian origin. A plaster-cloisonné decoration of gourds is carried out at several points along the Central American Highland, and its prototype may be represented in pottery vessels from north-western Mexico, which are ornamented by similar means. No example of the beautiful lacquer trays from Guerrero and Jalisco survives from the indigenous civilization, but although their pre-Columbian origin may be doubtful, their manufacture was an exclusive Indian property in Colonial times.

Art in Every-day Life

Thus vestiges of the ancient civilization exist today in some of the modern crafts. Those carvings and buildings which we have grouped under the Fine Arts were really projections of the common technical skill of the people. The virtual anonymity of most religious art fuses the humble crafts with the highest aesthetic expression. The attempts to inculcate "Art in the Home," so often made in modern times, would have been unnecessary in ancient Central America. While the little-known may well present fictitious advantages, particularly in the case of civilizations viewed through the mouse-holes of archaeological research, yet one feels that the Central Americans individually participated in their civilization to a greater extent than we do in ours

Ornaments of Pre-Columbian Central America

CENTRAL American ornaments resemble the antique jewelry of Europe in that skilful workmanship contributed more to the value of a piece than the intrinsic worth of the stone or metal. The cost of a jewel was not expressed by its size, as in the case of those modern diamond rings which reflect so clearly the bank notes tendered in payment.

The ancient Central Americans worked, as precious, such stones as jade, turquoise, obsidian, rock crystal, amethyst, opal, beryl, onyx, and carnelian, not to speak of other stones resembling these in textures and color. Around the Isthmus of Panama emeralds were used as ornament, and they have been reported also among the Aztecs. Metals employed for jewelry included gold and copper, but silver ornaments are extremely rare, owing to the metallurgical skill required for extracting the ore. If few of the stones which we moderns consider precious are represented in this list, it should be recalled that the ancient Mediterranean peoples, notably the Egyptians, Greeks, and Romans, knew equally little of our modern gem stones. Their ideas of value were certainly as developed as our own, but to them the sources for modern precious stones were almost completely closed.

The stone most generally esteemed by the Central Americans was jade. The New World varieties are distinguishable from the Asiatic jade, not only in chemical composition, but also in that elusive trait called "feel." Considerable mystery surrounds the exact origin of American jade, because no natural deposits have yet been found in Central America. The few specimens that reveal the original shape of the raw product suggest that jade was collected in bowlder form from stream beds but was not mined from the veins. It is quite possible that the more accessible places producing jade have been effectually gleaned of the precious substance by the ancient inhabitants, even as the Spaniards in the Colonial period exhausted the gold deposits which could be worked by hand. From the general distribution of jade objects according to the towns listed in the native manuscripts as paying tribute in that medium, the chief source must have been within the limits of the modern states of Oaxaca, Guerrero, Chiapas, and southern Vera Cruz. Costa Rica also produced much jade ornament, but the workmanship is not comparable to that of the north.

The value of jade to the Central Americans can be authenticated in various ways. The finest work and most skilful sculpture are lavished on objects of this stone. The tribute rolls show a constant demand for jade beads and ornaments. The Nahuan word for jade "chalchihuitl" and its hieroglyph were used with the connotation of "precious," and in describing the adornments of gods and chieftains, the chroniclers refer to jade in the same luscious way that we describe the diamonds of the mighty in our own society. Jade was prominent in the lists of gifts made by the native rulers to the Spaniards at the time of the Conquest. Finally, we have the testimony of the Conquistador, Bernal Diaz, our most engaging first-hand source on the Ancient Mexicans. In describing how the Spaniards looted the treasure of Montezuma's father, previous to their disastrous sortie from Mexico City during the Noche Triste, he says,

" . . . Many of the soldiers of Narvaez and some of our people loaded themselves with it (gold). I declare that I had no other desire, but the desire to save my life, but I did not fail to carry off from some small boxes that were there four chalchihuites (jades) which are stones very highly prized among the Indians, and I quickly placed them in my bosom under my armor, and later on the price of them served me well in healing my wounds and getting me food." No one who has read *The True History of the Conquest of New Spain* would ever doubt Bernal Diaz's practical sense of economic values.

Uses of Jade in Central America

The uses of jade were manifold. Axes and chisels were ground out that were not only aesthetically pleasing in their polished symmetry, but also, due to their hardness, extremely useful in carving softer stones for major sculptures. Ornaments comprised sets of beads, often matched as to color and size, ear-plugs, and pendants. Some of the ear-plugs were too large for human use, and this type of jewelry must have been made especially for the statues of the gods. Little pendants often engraved with floral designs or human figures are most pleasing, since they combine the natural luster of the stone with the balance of design inherent in Central American craftsmanship.

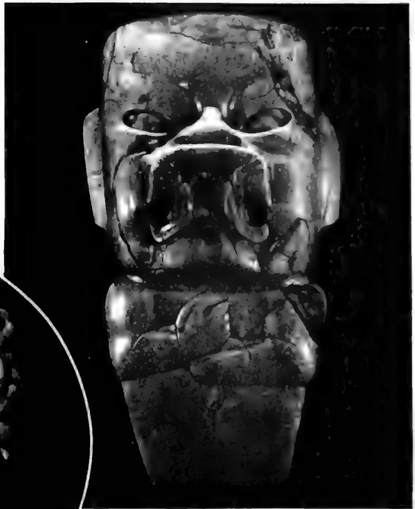
The process of manufacture must have been laborious, to judge from the unfinished fragments that have been found. The jade pebbles were often sawed into slabs by means of a string of rawhide used in connection with a rude abrasive like sand and water. Pecking and grinding must also have helped to reduce the irregularities of the natural stone. In the Oaxaca specimens especially, one sees evidence that a circular drill of bone or reed was used to engrave many elements of the decorative design. Some of the secondary details may have been brought out by sharp-edged flakes of obsidian. Finally the artisan imparted a lustrous polish to the specimen.

Main Steps in Working Stone

Prof. M. H. Saville acquired for this Museum a series of onyx vases that illustrate very neatly the main processes in working stone. First there was the primary stage of pecking out the block into the desired external form. The next stage lay in hollowing the interior by isolating with a tubular drill thin columns of stone, which could be readily broken out. A third step consisted of smoothing off the irregularities left by pecking and boring. Then the final details were added, and a general burnish completed the vessel. There is no doubt that this general method applied to the working of all the harder stones, with the substitution of sawing for drilling when the need demanded.

Yet the true beauty of jade is expressed by a series of small sculptures that bring out in miniature all the consummate design of the major plastic art. These small idols, like the Necaxa "tiger" and the larger votive axe from Vera Cruz, illustrate that element of monumentality which the better examples of Central American sculpture possess. By the term "monumentality" I mean the capacity of a carved figure to be indefinitely enlarged or reduced so that the sculpture, due to the balance of the elements involved in the composition, is neither distorted by the one nor diminished in dignity by the other. The Necaxa tiger, although only three inches high, is as impressive as if it were thirty feet. The Ocosingo jades, representing softer influences from the Maya country, lose nothing in comparison with the monumental reliefs with which the Mayas enhanced their stelae and temple walls. In fact, from our modern point of view, we can comprehend these minor carvings more readily than the great, since a *bibelot* one can keep and handle, but mas-

Jade is among the hardest of stones, and was most precious to the ancient Central Americans. They worked it without metal tools, so that the manufacture of ornaments like these must have required months of labor. New World jade can readily be distinguished from the Old World variety



Jade and Jadeite

The three jade sculptures shown on this page are among the treasures of the American Museum of Natural History. The middle photograph represents a small figure in the Maya style from Ocosingo, Chiapas. The top and bottom figures represent the same tiger-faced divinity. The seated figure is a little more than three inches high, but the upper one is more than a foot, and is the largest carved jade from Central America. Both carvings may be the work of the semi-mythical Olmecs of Vera Cruz

sive religious sculpture seems to belong to the god in whose honor it was created.

Substitutes for Jade

Many greenish stones, like porphyry, serpentine, and wernerite, the native jewelers worked in a manner similar to jade. Perhaps they could not distinguish these minerals from jade, or perhaps they knew that through the substitution of softer stones they could attain the same effect achieved in the harder and rarer medium. That extraordinary group of sculptures, attributable perhaps to the legendary Olmecs, depicts people with tiger and baby faces, both in jade and other stones.

The work in rock crystal, due to the excessive hardness of the material is, from the technical point of view, even more impressive than the jade sculpture. A few examples exist from various sites of beads and pendants. The most famous example, however, is the nearly life-size skull in the British Museum, and a miniature, illustrated for the first time in these pages, is one of the treasures of the American Museum of Natural History. The rock crystal vase, found by Doctor Caso in Tomb 7 at Monte Alban, represents even more strikingly the days of patient work that the creation of one of these masterpieces must have consumed, in the absence of any of our modern mechanical aids.

Ear-plugs and labrets of obsidian (volcanic glass) ground so thin as to be almost transparent, indicate that this useful substance was treated on occasion as a gemstone, and sometimes it was used as a material for sculpture. Even iron pyrites, commonly ground to make mirrors, was at least in one instance carved, as is attested by a lovely example in the Trocadero. Amethyst, opal, carnelian, and the like have been utilized as beads, while turquoise was used above all for mosaic work. The accounts of the loot of the Conquistadores mention emeralds, but they may have been exceptionally fine jades. In fact, of all the stones treated as precious by the Central Americans, jadeite and nephrite produce the most conspicuous examples of the lapidary's finesse. In civilizations so essentially religious in character as those in Central America, it is to be expected that the work in their most precious stone would produce a sculpture comparable in every way, except size, to the best monumental examples.

Although we have insisted that jade was more valuable than gold to the ancient Central Americans, and Bernal Diaz quotes Montezuma's ambassador as saying "that these rich stones of chalchihuite (jade) . . . were of the highest value, each one being worth more and being esteemed more highly than a great load of gold," this precious metal none the less had value among the Central Americans. Copper was also worked as ornament, but it was more commonly fashioned into tools. On the other hand, gold, save for some sporadic mentions of fishhooks, seems to have been reserved for ornament.

The Origin of Gold Work Technique

The techniques for working gold were apparently invented in northern South America. Indeed, Colombia and Ecuador have produced in sheer bulk the greatest Indian treasures exhumed in the New World. From these countries the gold worker's art spread through Panama to Costa Rica. Perhaps because the sources of the raw metal were negligible, there is no further great development of gold working, until one reaches southern and central Mexico. There we find the cleverest goldsmithing in the New World, although no addition seems to have been made to the fundamental techniques of manufacture imported from the South.

How Gold Ornaments Were Made

The Central Americans apparently knew nothing of smelting or other methods of separating the metal from the ore, for they extracted grains and nuggets of gold from river beds. This raw metal they melted

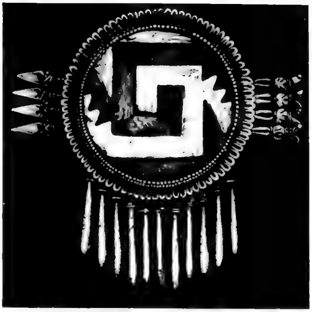
This tiny rock crystal skull represents countless hours of labor, and is one of the three finest specimens in the world. It is probably the work of an Aztec lapidary

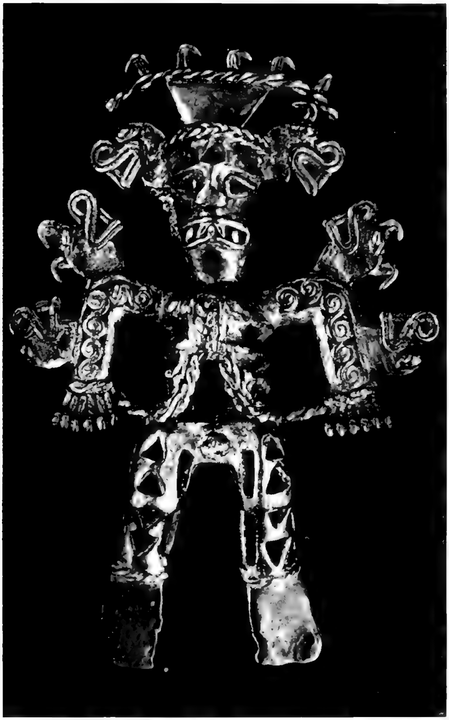
Crystal, Copper, and Serpentine

Copper was occasionally used for ornament, as is attested by this large bell sculptured in repoussé. The negroid features suggest a point of origin in southeastern Mexico

The little baby-faced figure to the left resembles the jade figure on page 77. The statuette is of serpentine, and the technique of carving suggests an imitation of the effects obtainable in the harder green stone, jade

This ornament (after Saville, 1920) is an exquisite example of Mixtec jewelry in the National Museum of Mexico. It imitates a feather-mosaic shield and the background of the design is turquoise inlay

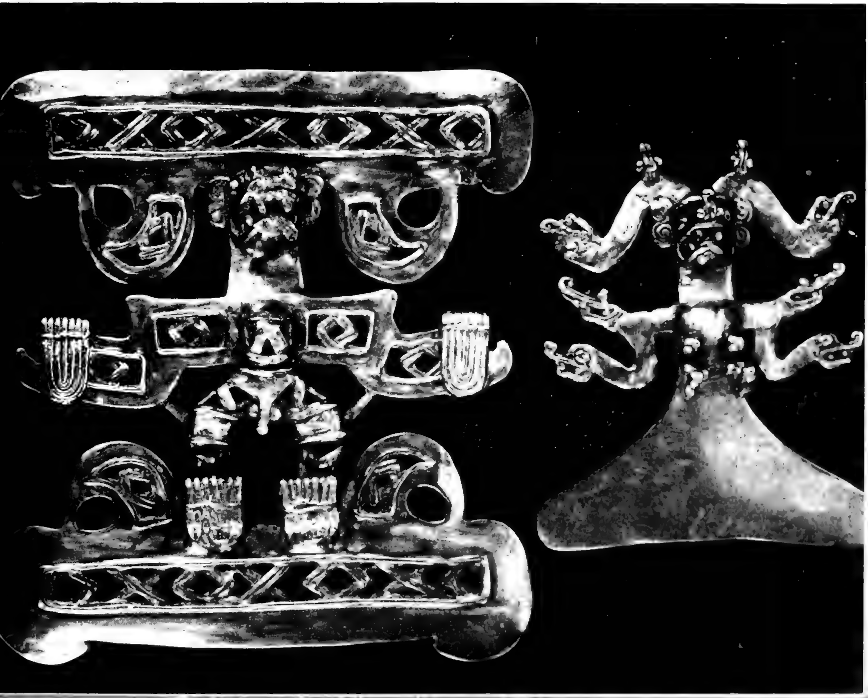




Central American Goldwork

The gold ornaments in the photograph above and at the lower right illustrate the barbaric jewels of Panama and Costa Rica. However, a strong sense of design gives to the four massive brooches a highly decorative effect. The group of five little animals (right, above) is more naturalistic in treatment, although a bird-headed monkey is a beast met more commonly in mythology than in a zoo

The three little ornaments above (after Saville, 1920) came from Oaxaca, and show the extraordinary skill of the Mixtec gold workers in their reproduction of a harpy eagle, a monkey, and a horned owl. Note especially the treatment of the owl's feathers. It is a tragedy that so much of this lovely ornament found its way to the Spanish melting pot



down and worked either by hammering or casting. This latter method is extremely ingenious, since it is like the European *cire-perdue* process. The pattern to be cast was engraved on specially treated clay over which was spread a layer of wax. The wax-covered pattern was then coated with more clay through which a wax-filled aperture was made. The mold was then baked, during which process the wax melted and ran out. The molten metal was poured into the resultant cavity, and when the gold had cooled, the mold was broken in order to extract the ornament which, save for a final polishing, was then ready for use.

The Central American goldsmiths knew how to plate copper with gold, and in Mexico they sometimes fused gold and silver into a single ornament. According to contemporary accounts, animals were made with movable legs, and fish with the scales so cunningly jointed that they wriggled. In Mexico they knew how to beat out gold leaf and apply it to objects of wood and stone, while there was considerable work in repoussé, which involves the beating out of a pattern in relief from the reverse of a gold or copper plate.

The regions producing gold ornaments are characterized by various types and styles of presentation. A rich gold art emanates from a chieftain's tomb in the province of Coclé, Panama, scientifically excavated by the archaeologists of the Peabody Museum of Harvard University. Here delightful animal figures contrast with the austerity of heavy ornaments and ceremonial discs in repoussé. Another group of gold objects comes from Costa Rica in the magnificent collection of Minor C. Keith, half of which is on view in the American Museum of Natural History. There are close parallels between this art and that of Panama, and here also one may enjoy the fresh vitality of little animals like frogs, crabs, and armadillos, as well as marvel at the bulk of formal ornament. An earring representing an animal seated in a swing indicates a quaint humanitarianism unwilling to allow even an ornamental beast to dangle by its neck. A whole collection of birds of various sizes could serve as models to jewelers today, so marked is the *chic* of the cleverly conventionalized forms. There is a considerable amount of copper plating and copper alloy that attest to some skill in metallurgy.

In the region occupied by the great Maya cities, there has appeared even less gold than jade, and both seem to owe their presence to trade. The Sacred Well at Chichen Itza, source of the greatest treasure hitherto found in the Maya area, yielded gold ornaments obtained from as far as Costa Rica to the southeast and southern Mexico to the southwest. It is not until the frontier between the Highland and Maya cultures is reached that we find the great development of gold working.

Notable Examples of Gold Work

According to Prof. M. H. Saville, whose *Goldsmith's Art in Ancient Mexico* is the authoritative work on this subject, northern Oaxaca produced more notable gold objects than any other section of Mexico, and this statement was made before the discovery of the treasure in Tomb 7 at Monte Alban. Nor can this rich harvest be entirely due to the drain put by the Spaniards on other parts of Mexico, since they were as active in Oaxaca as anywhere else. A soldier named Figueroa, according to Bernal Diaz, gave up trying to conquer the Indian tribes of Mixteca and "determined to undertake the excavation of graves in the burial places of the Caciques of these provinces, for he found in them a quantity of gold jewels . . . and he attained such dexterity that he took out from these over five thousand pesos de oro in addition to other jewels obtained from the pueblos." The enormous yield of Doctor Caso's remarkable discovery at Monte Alban gives an idea of the scope of the gold-worker's industry there. Fin-

ger rings, to wear below the knuckle and at the first joint, bore representations of eagles executed in filigree. Necklaces arranged in decorative tiers and massive gorgets depicting gods and religious symbols gave evidence of a sumptuous ceremonialism. Pearls also were scattered about the tomb and innumerable fragments of turquoise attested to disintegrated mosaics. Sophisticated as was the subject matter of the Monte Alban jewels, the outlines of some of the gorgets show the southern ancestry of the goldsmith's art in Oaxaca.

Museum Pieces

The collections of the American Museum reveal a few consummate examples of gold work. A small owl's head, complete even to the overlapping feathers, corroborates the tales of the Conquistadores and shows a technical precision not unworthy to be compared with Benvenuto Cellini's artistry. A haughty little harpy eagle head combines naturalism with a strong sense of decorative values, and a large lip ornament representing an eagle head subordinates naturalistic detail to design, without distorting the essential realism of the reproduction. Even beads are carefully worked into forms which are as satisfactory individually as they are when grouped as a necklace.

The Aztec gold work, thanks to the assiduous looting of the Spaniards, has almost completely disappeared. We know that there was a guild of goldsmiths, high in social standing, who inhabited a special quarter of Azcapotzalco and claimed descent from the legendary Toltecs. Conspicuous in the tribute sent by Cortes to his king was a golden "wheel" six and a half feet in diameter, inscribed like the famous "calendar stone" with the sun, day signs, and other symbolic elements relating to time as recorded by the Aztecs. Cortes was also the recipient of a necklace in which golden scorpions were a conspicuous element. How far the Aztec goldsmiths were influenced by Oaxacan styles the dearth of specimens from the Valley of Mexico prevents our saying, but in the lists of Spanish loot there is a general correspondence between the descriptions of the Aztec treasure and the different types of ornament recovered in Oaxaca.

The jeweler's art in Central America, as can be seen by the illustrations accompanying this article, is capably developed and appears less alien to our modern tastes than the major arts. Personal eclecticism and the joy of individual possession influence one's taste in ornament to a great degree. A contributory factor in the appreciation of an art is the possibility of incorporating examples in one's own milieu, a condition difficult to envisage with the major examples of Central American arts. However, to keep as a *bibelot* a jade ornament, or to wear a gold idol as a brooch or charm is perfectly feasible, since such an action involves no violent adjustment of aesthetic or ideological conceptions. Perhaps the sheer craftsmanship of the Central American jewel worker will lead us to as close an appreciation of Central American art as any other factor in these remarkable civilizations.

The Pottery of Pre-Columbian Central America

THE potter's art in Central America reveals an extraordinary development of imaginative skill. It seems little bound by those set requirements of ritual which governed artistic expression in the arts we have considered in the five preceding articles. Humble as are the uses of pottery, an almost infinite invention is displayed by the multiplicity of forms and decorative styles. The work in clay suggests that here the oppressive grasp of religion was relinquished, releasing the fancy thwarted in other directions. No other part of the world, China not excepted, shows such diverse forms and decorations as those displayed by pre-Columbian ceramics in the area between Chile and the Rio Grande.

In Central America, as elsewhere, the invention and practice of agriculture relieved man from his unremitting search for food, since the harvest created a store to satisfy his needs for months to come. The leisure thus gained gave him a chance to use his mind in directions other than the hunt, and led to the series of inventions and intellectual conceptions which culminated in the handful of great World Civilizations. One of the first steps taken by the early farmer was to devise means of conserving his winter food supply and of preparing it for palatable consumption. In the attainment of these ends, the development of containers of baked clay played a significant and highly important part.

Apart from its importance as an invention, pottery has a more complete historical record than any other phase of early culture in Central America. The hardness of baked clay renders it relatively immune from the destructive action of rot or fire, which have so affected textiles and wooden objects. Even when a vessel is broken, the fragments survive among the ruins of a building or in the village refuse heap. The lack of intrinsic value secured pottery from the cupidity of invaders, greedy for treasure. The common household functions of ceramic products cleared them of the stigma of heretical barbarism, which impelled the Conquistadores to destroy so much of the native religious art in Central America. The usefulness of pottery made it a usual equipment for the dead in their life beyond the grave, so that many complete examples have been conserved in burials, to satisfy later the rapacious curiosity of excavators. Thus the study of pottery, because it is both prevalent and indestructible, has become the backbone of archaeological technique, and by means of the local and tribal decorative styles it is possible to trace the history of early peoples by the fragments of their vessels. Unfortunately, the involved descriptions of pots and pans, which in consequence fill professional reports on excavations, effectively quench whatever interest the layman might take in them.

To absorb the full beauty of Central American ceramic form and design, one must look beyond the borders of the Greek aesthetic ideal. The exquisite shapes of Greek vases resulted from the harmonious principles devised to govern the proportions of their vessels, but lovely as were the results, these formulae restricted the range of forms. Central American pottery, in contrast, seems completely without such laws, so varied are the shapes. A more detailed examination discloses, however, the operation of rigorous local customs to which the potters strictly adhered. As the pueblo, or town, was the chief unit of group organization, there arose almost innumerable local

This vase from Miahuatlan, Oaxaca represents Macuilxochitl, the Mexican god of games and feasting. The simple lines of the vessel throw into vivid prominence the lively figure of the divinity. The design on his loin cloth and his necklace of gold and jade are faithfully represented

Ceremonial Vessel from Mexico

Left: This vase from Tepic, Mexico (after Lumholtz 1902) represents a turkey. The wing feathers and wattles of the neck are picked out in gold leaf

Below: Guatemala was the source of this elaborately carved vase (after Saville 1919) which is a masterpiece of Maya ceramics

Below: The glazed effect of this type of Salvador pottery was so greatly admired in ancient Central America that it was traded far and wide. This delightful example shows how successfully the potter animated the vessel by the use of a few simple lines

Above: This sturdy jar from western Mexico illustrates the architectural proportions of much Central American pottery. Structure is stressed, rather than concealed, as Central American art is relatively little concerned with ephemeral grace

Below: The pottery of Costa Rica is often lavishly ornamented, but in these examples painted designs are used to emphasize simple effigy forms. Note how the jars are supported in one case by a tripod, in the other by an annular base

Above: This vase from one of the earliest Central American cultures shows how excellent decorative effects could be attained by the use of a lustrous surface and a few simple lines

styles, differing widely from one another and giving to the whole of Central America the effect of aesthetic anarchy, so far as pottery is concerned.

While the shapes of Greek vases give the effect of defeating gravity by their graceful upward curves, the Central American potters seem to stress the difficulty of keeping their vessels erect. The greatest dimension is apt to be horizontal, rather than vertical, and emphasis is placed on the support which in the smaller vessels is usually a ring base or three or (less commonly) four legs. So constant is the use of a low center of gravity that vases with the "soaring" quality of the Greek urn are almost unknown. It is possible that the technical difficulties of building up a vessel with strips of wet clay may have necessitated a more solid structure than that demanded by the more rapid Greek process of throwing up a vessel on the potter's wheel.

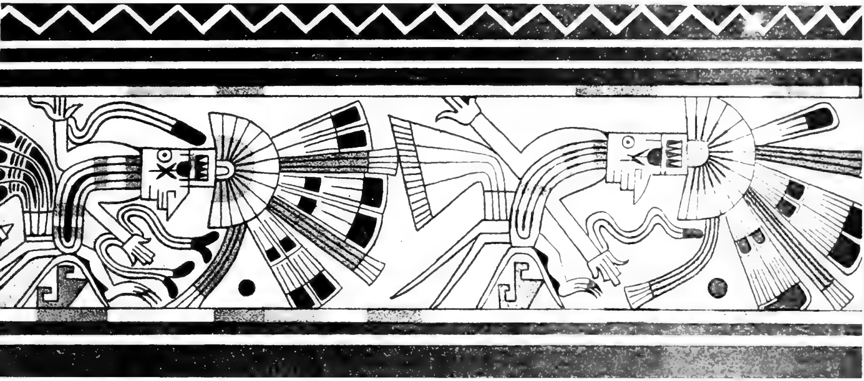
The shapes of Central American pottery are as eminently satisfying as the forms of natural objects. Some bowls are almost spherical and others have the form of a pear. Cylindrical vases of varying dimensions express a delicate grace if tall and narrow, or practical solidity if short and wide. By curving the walls slightly inward or outward, beautiful variations are obtained. Again, a bowl may be grooved to give the effect of a gourd, or else ridged spirally to bring up the high lights on its surface. Many vessels are made in two sections, a wall and base, and, by increasing the size of one or the other, not only are various delightful proportions attained, but also fields are created for a rich variety of decorative effects. In western Mexico occur especially attractive forms, which involve a curved base, with an almost horizontal shoulder, out of which protrudes a flaring neck.

The simplest form of decoration is to polish the exterior of the vessel. The methods of firing the pots seldom produce an absolutely even color, so that the glossy surfaces suggest the tones of polished fruits or the glossy coats of animals. Black, for example, is seldom jet black, but more the shade of well-used walnut furniture. Reds range from the brown tones of a russet apple to the solid shades of red peppers, dried and polished. Browns merge into black at one extreme and dwindle through imperceptible gradations to a matt yellow. Warm orange tones characterize the clays of several ceramic families, while others show steely gray shades. Such lustrous tones enhance the pure forms in a way that painting never can.

There are numerous cases of effigy vessels, where in the simplest stages, a head, limbs, and tail, added to the pot, give it a pleasingly alive appearance. Sometimes the head alone is added and the anatomical details are incised. In extreme cases the animation of a pot is carried so far that it becomes a sculpture in clay, like the figures of western Mexico mentioned in a previous chapter. The most consistent use of effigy pottery is in the Plumbate Ware of Salvador, which has a vitreous surface and is the nearest approach to true glaze in Central America.

Since the tripod support was so important in keeping a vessel on an even keel, the Central American potter gave vent to his imagination in constructing this useful adjunct. One way was to make the legs hollow and insert pellets of clay, so that they became rattles. Often the supports were modeled into imitations of animal or human legs, and sometimes, in Costa Rica, Atlantean figures supported the bowl. The modeling of bird and animal heads was also thought a suitable means of transforming a functional necessity into an ornament. When a ring base was used, it was often painted or carved, and sometimes by closing the bottom, it was converted into a rattle.

Two other methods of decoration were in general use. One was to produce a decorative effect on the surface of the pot by incision or applying bits of clay. The second was to add a painted design. Which of the two was the earlier there is no means of knowing, since no really primitive culture has yet been discovered in Central America. If the Southwestern United States, which



Mexican Design

The sources for Mexican pottery designs are many and varied. In the upper right hand picture the purely conventional *grecque* is used, whereas the vase at the lower right is ornamented by the hieroglyph for one of the days of their month, which is a conventional representation of the reed. The jar at the upper left is ornamented in plaster cloisonné, and the central band (after Lumholtz, 1902) reproduces the design from a similar vessel. Such stylized human figures are rare in Mexican ornament

Above: This cover from a Zapotec incense burner shows the transformation of a vessel into a ceremonial sculpture

Left: The incensario at the left is much restored and comes from the Teotihuacan culture of the Valley of Mexico. It shows the building-up process utilized in this class of religious vessel

Below: This clay mask from Vera Cruz is a simple and straightforward piece of sculpture, yet it may have been used in connection with some elaborate creation like that on the left

Above: This life-sized figure from the Valley of Mexico is a remarkable technical achievement, requiring great skill in building up the sections so that they would not collapse of their own weight

The head at the upper right was one of a pair of effigy vases found with a burial of the Mazapan culture at Teotihuacan. Although treated sculpturally it is none the less a container. The large figure at its left, and the seated figure from Nayarit are pure sculptures. The photographs on these pages show in striking fashion the contrast between convention and naturalism in Central American art

show the transition between hunters and agriculturists, produce painted designs as the earliest ceramic decoration, the Argentine and the Eastern United States contain primitive tribes who incised and stamped their rude vessels. Therefore, in describing Central American ceramic decoration, we cannot follow an evolutionary plan.

Incising and carving the surface of a bowl were especially common. The cruder examples, from the earliest cultures yet found, show simple geometric patterns made sometimesafter sun drying and occasionally after the pot was baked. A striking development of this process was the Teotihuacan method of champlevé, in which, after a vessel had been fired and burnished, the polished surface was cut away to leave a figure in relief. Sometimes the effect was enhanced by rubbing red pigment into this roughened background. Some of the finest reliefs in the Maya country may be found on carved vases of this type from Yucatan, where great skill in sculpture and drawing raised the champlevé work from the secondary field of decoration to the primary one of Fine Art.

A type of decoration which is found in western Mexico and perhaps derived from this work in champlevé approaches the technique of cloisonné. In the Mexican examples a completed pot was covered with plaster and the desired design outlined by scraping the soft exterior down to the original surface of the pot. Into these scraped zones, plaster strips of different colors were laid, creating a harmonious, if fragile, decoration. Another method of ornament involved a covering of plaster, which was then painted in fresco. These plaster decorations could not have survived daily use and must have required special treatment for mortuary or ceremonial use. In fact, in several examples, a painted design has been concealed by a covering of fresco or plaster cloisonné.

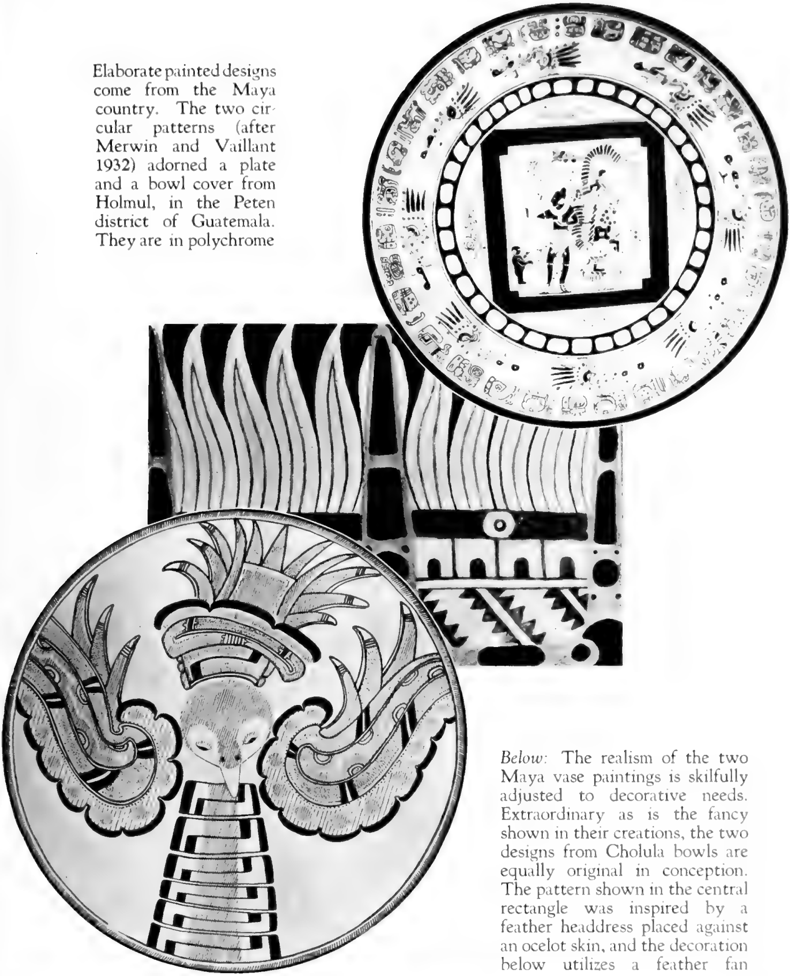
Another decorative style consisted of pressing a stamped design on to the wet surface of a bowl. This process, when repeated, gave a symmetrical series of ornaments in relief or intaglio. Even commoner was the attachment of decorative elements made in molds, which might represent floral patterns, human and animal heads, or else purely conventional designs. Clay vessels were sometimes touched up with gold leaf, like the celebrated Tepic effigy vase, and clay beads treated in the same way were thrifty imitations of the real thing.

Painted decoration involved a prevalent use of geometric design. As we have suggested in the section on Crafts, there is very strong evidence that the textile art with its complementary ornamental patterns was developed long before pottery. Since, in the Southwestern United States the designs painted on pottery are in direct imitation of the earlier basketry patterns, there is considerable likelihood that this practice was quite general in the New World. There was no orderly evolution of design from naturalism into conventionalization. The use of naturalistic elements appeared late, strictly governed by the requirements of harmonious design.

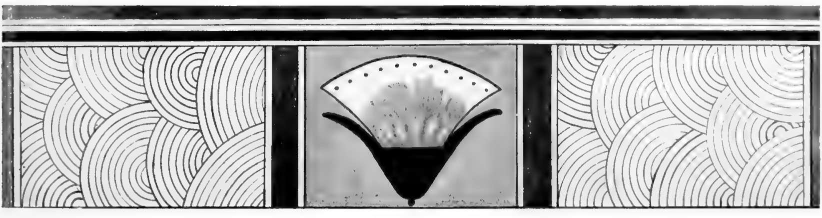
The arrangement of the design in most localities was in panels. Frequently these design units, when on the outside of the bowl, were arranged in threes, so that a complete pattern could be seen. This principle is based on a "rule of thumb" geometry, since a little less than a third of a cylindrical body can be viewed from the side. Continuous patterns, except for borders, are much less common. Besides the steps, grecques and volutes of geometric design, there were also conventionalizations of natural forms. Flowers, animals, hieroglyphs, religious symbols, were cunningly treated to make decorative effects. In the Maya pottery of Copan and Salvador the monkey was often used, since its elongated arms and tail were readily adaptable to the needs of design.

The colors include shades of white, red, yellow, orange, black, with occasional uses of blue and green. The disposition of the colors usually involves one for the background, another to outline the design, and a third to fill the patterns. Sometimes when

Elaborate painted designs come from the Maya country. The two circular patterns (after Merwin and Vaillant 1932) adorned a plate and a bowl cover from Holmul, in the Peten district of Guatemala. They are in polychrome



Below: The realism of the two Maya vase paintings is skilfully adjusted to decorative needs. Extraordinary as is the fancy shown in their creations, the two designs from Cholula bowls are equally original in conception. The pattern shown in the central rectangle was inspired by a feather headdress placed against an ocelot skin, and the decoration below utilizes a feather fan



Maya Pottery Designs

Left: The Maya used their script in decorative fashion. This vase from Guatemala, like the Holmul plate on the preceding page, utilizes bands of glyphs to divide off design fields

Below: The conventionalized pelican on this vase is carried out in red tones on a white background. This and the upper vase are after Gordon 1925

Left: This vase from Salvador is ornamented by designs in black and orange on a yellow field, while the Maya bowls on the preceding page show similar uses of warm red and orange tones with black outlines

realistic elements like a headdress or a butterfly are portrayed, they are used naturalistically. The fullest use of naturalism in color and design is in the celebrated "picture" vases from the Maya country which we have considered under Painting.

Besides pottery vessels, the work in baked clay extends to many other types of objects. The figurine cult, which contributes so much to the plastic art of Central America, absorbed much of the potter's inventiveness. Spindle whorls, the weights used for the wooden shafts in spinning cotton, become, in the hands of Central Mexican clay workers, beautiful little creations, with their lustrous red or black slips and delicately worked reliefs. The stamps for adorning cloth or the skin, are often of clay, and represent in their cutting skilful judgment of balanced design. Musical instruments like whistles, flutes and ocarinas require of the potter a knowledge of the physical properties of tone, while the cylindrical drums of Central America are often beautifully ornamented by carving or painting. A curious musical instrument, very rarely found, is the whistling jar which gives out a note by the air expelled when the liquid is poured out. The massive incensarios, used to burn incense before the temples, are as imposing from a structural point of view as from one of ceremonial art. Pipes, used presumably for ceremonial smoking, since cigarettes and cigars were the usual method for consuming tobacco, are frequently exquisitely polished and very well proportioned. Censers or incense ladles often received treatment comparable to the best of the ceremonial art.

The relationship of these Central American clay forms to the art of the present day brings one face to face with the besetting difficulty of modern European art. We are in an age of revolution, intellectual and artistic as well as political and technical. There is a tendency to abandon individualism for group action, and, in the fields of architecture and the decorative arts, function and the relationship between the material and the form tend to suppress the individualism of the craftsman's personal expression. The copying of alien art forms is arid when it is not jarring, so that it would be stupid to utilize in our art today the *content* of Central American aesthetic expression. On the other hand, the impersonality of Central American art, which expresses a mass life under divine direction, dovetails well with our modern disciplines under mass production and mass movement.

The Chicago World's Fair, intended for the absorption of millions of people, produces the anonymous effect of the work of thousands of artisans and engineers, but not the genius of an individual. Much this same spirit permeates the art of Central America. The principles of design and form are no less inherent in our discipline by graph, blue print, and mathematical formula than in the ancient Central American rule by ritual.

This and the preceding chapters have been intended to show the various aspects of Central American art without insistence on the complicated historical background. The relationship of the individual Central American to his art, we can probably never know precisely, although we can be certain it was not aesthetic in our modern sense of the word. On the other hand, we moderns can extract a great deal of pleasure, even inspiration, from the contemplation of the works of these gifted people, if we lay aside the tenets and traditions of our past art history to examine Central American art from the viewpoint of our modern industrial age.

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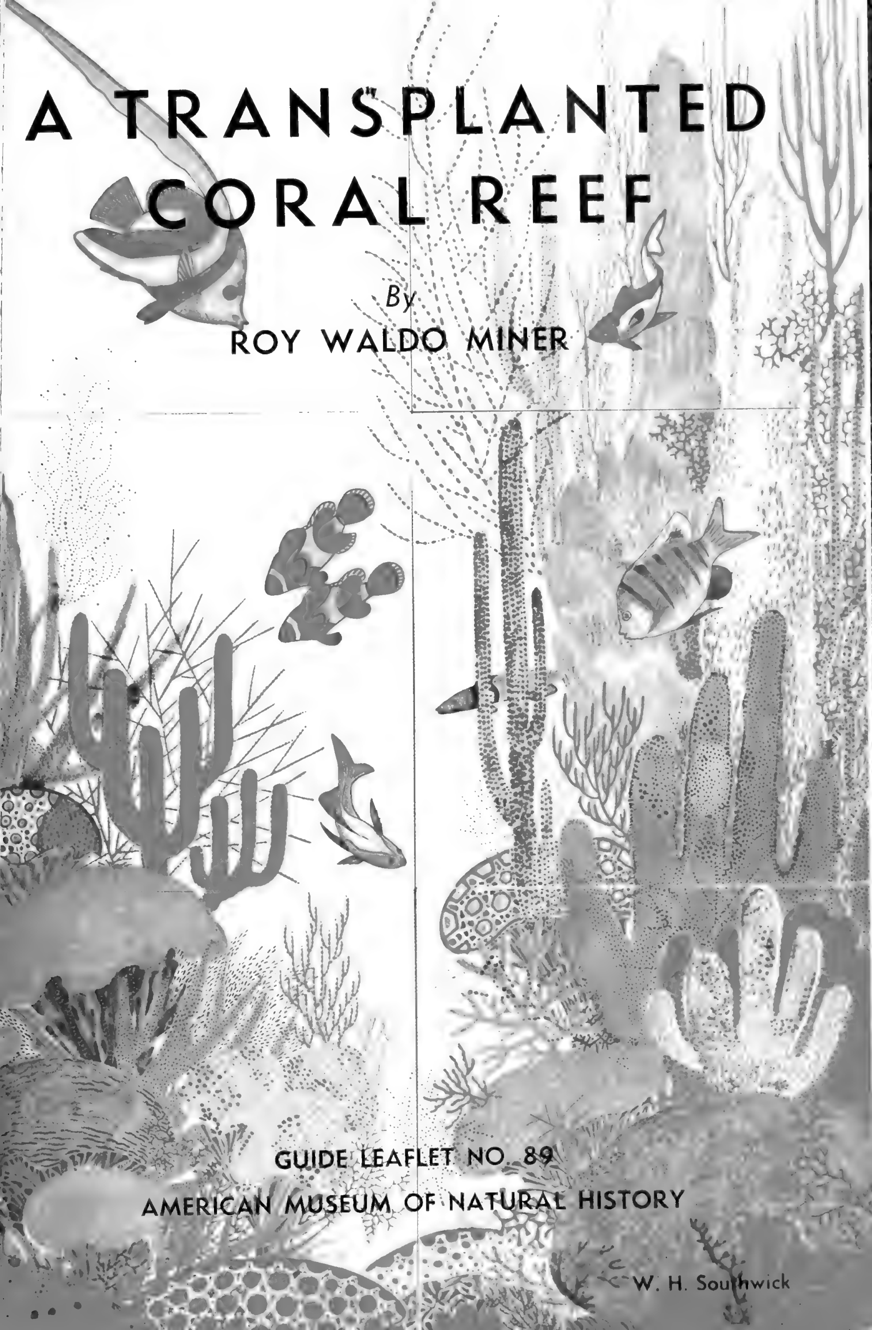
A TRANSPLANTED CORAL REEF

By

ROY WALDO MINER

GUIDE LEAFLET NO. 89

AMERICAN MUSEUM OF NATURAL HISTORY



THE COVER

A SUBMARINE DESIGN

on Tile

by

W. H. SOUTHWICK

[*Reprinted from* NATURAL HISTORY, *April, 1935, pages 273–285.*]

A Submarine Coral Forest on the Andros Reef

Photograph taken twenty-five feet below the surface. The studies for the Coral Reef Group were made not far from this spot

A Transplanted Coral Reef

A description of the Bahaman Coral Reef Group in the Hall of Ocean Life at the American Museum

By Roy Waldo Miner

Curator, Living Invertebrates, American Museum

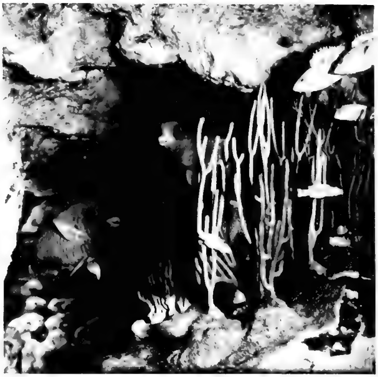
After twelve years of complicated and difficult work, the department of living invertebrates at the American Museum has opened to the public what is, perhaps, the most remarkable museum "group" ever constructed. Created from forty tons of coral that was gathered from the sea bottom in the Bahamas, this elaborate exhibit is tied together and supported by an intricate fabric of structural steel which, in itself, weighs eight tons. In the course of the work, Doctor Miner, the author of the following article and the originator and designer of the exhibit, has led five expeditions to the Bahamas during which the studies and the collections utilized in building the group have been made. His account and description, therefore, are of special interest and value. — The Editors

As you enter the Hall of Ocean Life on the gallery level at the American Museum, the new Bahaman Coral Reef Group may be seen at the farther end directly opposite the observer. Its proscenium arch rises from the main floor of the hall, passes through the gallery, and surrounds the upper part of the group in a half-circle at a height of thirty-five feet.

The portion of the group above the gallery presents a vista of coral island with waving palm trees, quiet lagoon, and tropical sky with trade-wind clouds drifting across it. A flight of flamingos dots the background of snowy clouds with flecks of rosy color. On the distant horizon, apparently a mile or so away, the low-lying shore of Andros is visible, soft with its long fringe of coconut palms. For the scene is laid in the Bahamas, along the eastern coast of its largest island mass, where the finest coral barrier reef in the West Indies parallels the shore. The small island in the foreground is Goat Cay, just back of the main reef, the location of which, at the left, may be seen more clearly, at closer view.

The section of the group below the gallery, even at this distance, obviously depicts the coral forest as seen from the bottom of the sea. On either side, staircases permit visitors to descend from the gallery, and, as it were, plunge beneath the waves to stand on the ocean floor and study the coral reef from that point of vantage, as the members of the Museum's expeditions did in obtaining the material and observations for this group.

Now let us pass around the gallery and view the upper scene at close range. We are looking over the rail of a yacht which has been anchored fore and aft in a channel of the reef. The wind-swept vegetation of Goat Cay and its shore of eroded limestone are now clearly visible. At the left, the dark blue waters of the Tongue of the Ocean, an arm of the sea more than a mile in depth, roll in, breaking heavily upon the barrier reef in long lines of white foam. The coral barrier rising from the crest of a submerged precipice, the summit of which is from twenty to forty feet below the water surface, consists largely of huge branching



(Above) The Cave of the Blue Parrot-fish guarded by its white-jawed denizens

A squirrel-fish swims over a post of orb coral toward a triple-headed brain coral, below which crawls a bear-crab

(Below) Two members of a school of black angel fish, with spadelike bodies, their dorsal fins with trailing filaments

A spiny lobster peers forth from its den among the corals, waving its prickly antennæ

A vista through branching elkhorn corals. Black angel fish swim by in stately procession. In the foreground is a group of three mushroom-like orb corals

trees of the elkhorn coral, the tips of which break the water surface at low tide. The trade winds, blowing continuously from the southeast, dash the waters of the Tongue of the Ocean against the face of the submarine precipice and the tangled growth of the stony coral trees, causing upwelling currents which mingle with the ranks of, snowy-crested surf.

THE UPPER SCENE

Inside the reef the force of the waves is broken, and they slide with diminishing force in intersecting cross currents across the quiet waters of the sheltered lagoon, where vessels may lie safely at anchor, except in times of hurricane.

In the distance the shore of Andros shows native villages snuggling among the coconuts, while, at the right, the open waters of a wide strait, Middle Bight, lead the eye into the quiet peace of a broad inland sea, dotted with islands.

The towering trade-wind clouds rise on the heated air currents of a June day 25,000 feet into the air, where their fleecy summits stand out against the deep blue of the tropic sky. Outlined against them, the long file of scarlet flamingos flies in stately procession inland to follow the coast to the great flamingo colony in southern Andros.

Our boat is anchored close to a little rocky cay, a point of which projects in the right foreground, carved and honeycombed in fantastic hollows.

Looking over the rail, our eyes penetrate the transparent waters right down to the bottom of the sea, and, through their lucid depths the wondrous submarine gardens are disclosed with all their beauty of form and color, tempting us to a closer view.

So, descending the staircase, we pass beneath the gallery level, and well may we imagine that we have donned diving helmets and have penetrated the depths, for all the glory of the coral world bursts upon the view. We are gazing into the heart of a magnificent coral forest. The branching trees of the elkhorn coral (*Acropora palmata*) rise, tier on tier, above our heads, breaking the water-surface sixteen feet above. An arching sea cave at the right, piercing a fantastically carved and eroded submarine ledge, leads into a tortuous tunnel filled with mysterious purple shadows and soft lights filtering through an opening in the rear. This is the Cave of the Blue Parrot-fishes, and two of the heavy-bodied cerulean tenants may be seen nosing their way out of the cavern entrance, while a third swims slowly back and forth as if guarding the back door.

Between the rocky wall and the spreading tangle of the coral forest a vista opens out into the watery world, melting by degrees into the opalescent and luminous blue mist which everywhere terminates our vision in the distance. The light of the sun filters through the aqueous depths, lighting up vague forms of grotesque outline. The waters in the Bahamas are of unbelievable transparency. Crystal clear in the foreground, everything stands out as sharply as in the open air. Under favorable circumstances, at depths ranging from fifteen to twenty-five feet, one can see a hundred feet or more before visual penetration is limited by the gathering density of the sun-lit azure fog.

The sea floor, around one's feet, blooms with every variety of stony splendor in crowded array. Not an inch is wasted. As far as the eye can see through the watery aisles the abundant coral growths stand in shouldering clusters. Here is a group of three green, dome-shaped caps rising close together on stony pedestals for all the world like giant mushrooms. They are the annular orb corals (*Orbicella annularis*), their green summits suffused with delicate clouds of rose, where areas of the tiny flower-like polyps show their expanded tentacles. Near by, a double-ridged brain coral (*Diploria cerebriformis*), bright orange in color, projects its rounded knoblike head, mounted on a contorted column, its surface covered with complicated meandering sculpture, suggesting the convolutions of the human brain. A little farther to the left another growth of the same species has developed an odd triple cluster of heads upon the same stem. A beautiful elkhorn immediately behind it spreads an unusually symmetrical frond of broad palmate branches like a giant fan. Crowding upon this from the rear, phalanxes of orb coral

Nassau

Grouper

This great, striped and mottled fish is often so camouflaged among its surroundings as to be practically invisible. Should it swim over a patch of white sand, its colors fade to harmonize. Opposite the grouper a giant sea anemone spreads its waving tentacles. At the lower right is a fragile bush coral

posts stand, grouped like sentinels, among golden yellow nuggets of pore corals (*Porites astreoides*) which cover every available space on the sea floor between their stately neighbors.

In the center foreground, spreading clusters of the fragile, finely divided bush coral (*Acropora prolifera*) overarch the hiding place of the spiny lobster or crawfish (*Panulirus argus*), while on a little sandy patch at the lower left a bear-crab (*Scyllarides æquinoctialis*) is warily inspecting a large spiny sea urchin (*Centrechinus antillarum*) which radiates its black, needle-like spines in all directions, reminding one of a submarine porcupine. Clusters of yellow-tipped finger corals (*Porites clavaria*) are crowded at the base of a great dome of sidereal coral (*Siderastrea siderea*), most massive of all species. This particular specimen weighs a ton and a half, and, when collected, required the combined efforts of twelve men to roll it up the beach.

THE LAIR OF THE MORAY

Behind the finger corals arches a low cavern, the home of the dreaded green moray (*Gymnothorax funebris*), which inhabits crevices of this sort. It is a heavy-bodied eel with small head furnished with sharp, needle-like teeth. It is well for a diver not to thrust hand or foot into such a crevice without first investigating with a lance, for the creature will dart out its head, biting viciously at any intruder. The eroded coral forming the arch and sides of this cavern is overgrown with purple, green, and yellow sponges, some forming clusters of chimneys, others made up of low, rounded mounds crowded closely together.

Everywhere among the stony coral structures rise dense growths of gorgonians. These are the plantlike sea-bushes, sea whips, sea feathers, and sea fans. When one observes them through a glass-bottomed boat, one can see them wave back and forth with the ocean currents, and they are often mistaken for vegetation by the casual observer. Nevertheless, they are animal structures with a core built of horny material, instead of having a limy "skeleton," as with the reef-building corals. There are some gorgonians, known as "sea clubs," with fully expanded polyps, shown in the group near the moray's den. The clubs are purple, but, when the light-green polyps are fully expanded, that color is concealed and the clusters appear to be masses of heavy, feathery plumes. When one touches them, however, the green polyps are suddenly withdrawn within the clubs, and the color seems to change into purple as if by magic.

The sea feathers (*Gorgonia acerosa*) are large, heavy, magenta-purple plumes reminding one of ostrich feathers. Many of them can be seen in the group. When fully expanded, the fine branchlets are covered with rows of tiny corn-yellow polyps suggesting the florets of goldenrod.

The sea fans (*Gorgonia flabellum*) are strikingly conspicuous on the reef. As their name implies, they are broad fanlike expansions, characterized by a lacy texture of fine meshes. Purple and yellow sea fans are seen growing side by side and are of the same species.

The fish-life of the coral reef is very abundant and characteristic. When, equipped with diving helmets, we wandered, half walking, half gliding, through the coral forests of Andros, or the sea gardens of Rose Island, we seemed to be in another planet, where trees were of tinted marble and grew with interlacing branches gnarled in weird contortions from a forest floor beset with enormous mushrooms, also of stone; where animal flowers expanded and contracted on every hand, and dim figures moved silently in dark, mysterious caverns. We ourselves glided almost as in a dream, for, though we wore helmets weighing sixty-five pounds in the world above, down here among the corals we seemed to have lost all weight, and, borne up by the aqueous medium, became part and parcel of our ethereal environment.

Then, suddenly, almost out from nothingness, our watery atmosphere became shot with living jewels, brilliant colors scintillated in the sunlight that came dancing down from the motile liquid silver film of the water surface above. Fishes of every hue were all about us. Chromids shone with sapphire, blueheads, — the males, true to their name, hooded with rich azure, col-

Transplanters of the Coral Reef. Doctor Miner conversing with Chris Olsen, chief modeler of the group. At left, Herman Mueller, glass modeler. Dr. George Childs, scientific artist; at right, Worthington Southwick, colorist. Bruce Brunner, assistant modeler

General view of the Coral Reef Group seen beneath the pontoons of the Lindbergh plane. (Above) the Coral Lagoon at Andros Island. (Below) view into the heart of the coral barrier from the sea floor

lared with black and snowy white, with bodies of a brilliant emerald-green; the females, with salmon-colored cheeks, their bodies green and white, with black stripes; the young, yellow like canary birds, often variegated with black blotches and areas of green and pink. As we wandered about, larger species sailed into view, gaudily decked out in gay patterns.

FISHES OF THE CORAL REEF

Let us return to our group, for here we have endeavored to give a similitude of life as faithfully as possible, though with a feeling of despair at the inadequacy of our efforts.

Many blueheads (*Thalassoma bifasciatum*), as described above, may be seen flitting about in various parts of the group, especially toward the right. The sergeant-majors or cock-eye pilots (*Abudefduf marginatus*), are the rather deep-bodied little fishes, with vertical black bars over a body shading from yellow to white, in the upper right-hand corner, near the top of the rocky ledge. They must not be confused with the banded butterfly-fishes (*Chætodon striatus*). These are thin, flat, and much smaller. They are seen as if flitting like butterflies, in the lower part of the group, to the right of the center, where they are associated with blueheads and slippery dicks (*Iridio bivittata*). These latter are little, elongate fishes, with a continuous fin along the back, their color blending through pale tints of rose, green, blue, and black markings on an orange and yellow ground.

The large fishes swimming in a school down past the upper portion of the cliff are yellowtails (*Ocyurus chrysurus*), so-called because they have a bright yellow stripe along the side of the body continued into a completely yellow tail. They are excellent foodfishes and are eaten throughout the West Indies.

An interesting situation is occurring in the upper part of the group. A school of houndfishes (*Tylosurus raphidoma*), conspicuous because of their slender, silvery bodies and long pointed beaks, is being broken up, the fishes scattering desperately through the coral branches. The reason is not far to seek. Lurking just under the water-surface, at the upper left, and gliding through the coral branches, is a large barracuda (*Sphyræna barracuda*), four and one-half feet in length. Its baleful eyes are fixed on its prey as it slides swiftly toward them, the undershot jaw slightly open, showing an irregular assortment of long, cruel teeth. The barracuda are abundant in tropical waters, where they are dreaded even more than sharks. Fortunately, they seem to prefer open lagoons, and only occasionally visit the reefs.

In the middle distance, below the houndfishes, a large school of black angel fishes (*Pomacanthus arcuatus*) sails slowly by in stately procession. They are deep-bodied, dark gray in color, often with indefinite vertical bands, and with trailing filaments prolonging their large, flat, dorsal and anal fins. Compare them with the blue angel (*Angelichthys ciliaris*), a brilliantly blue, flat-bodied fish, in the middle part of the group, nibbling at a purple sea feather. The remarkable peacock blue of its body and fins is narrowly bordered with scarlet which shades into trailing, bright yellow filaments above and below. Near by, a school of yellow and black rock beauties (*Holacanthus tricolor*) flits in and out among the corals.

NATURE'S CAMOUFLAGE

Slightly to the left of the lower center, just behind a growth of the fragile bush coral, a large Nassau grouper has emerged halfway from under a coral arch. Its brown-and-tan striped and mottled color pattern acts as a camouflage with the variegated surroundings and so completely conceals it that one can gaze directly toward the fish for several minutes without noticing it, in spite of its size. The Nassau grouper is one of the prized foodfishes of the Bahamas, and the people of Nassau pride themselves on the savory chowders made from it. When exploring a reef with diving helmet, one should be wary of cornering one of these groupers, for when irritated, they are capable of suddenly turning and giving a vigorous nip. It is interesting to watch a grouper swim out over a patch of white sand. As it does so, the mottled color pattern fades out before one's eyes and the

fish becomes pale and sandy in color, completely harmonizing with its background. As it turns and goes into the reef again the color pattern returns with all its original vividness.

Around the grouper's arched hiding place, several clumps of the beautiful lettuce coral (*Agaricia agaricites*) are attached to the dead coral rock. They have beautifully foliated expansions in undulating clusters, richly tinted with rose-madder, pink, and purplish-blue, often with suggestions of yellow. On one of our trips, our artists made careful color sketches of these corals in the living state. Then the specimens were collected, bleached, and brought back to the Museum, where the color was restored artificially in oils. On a subsequent expedition, we carried samples of these painted corals back with us, took them down undersea, and placed them on the reef, beside living specimens. We were greatly gratified to find that the artists had copied the colors so faithfully that they could not be told apart when viewed at arm's length.

CORAL GARDENS

Almost directly opposite the nose of the grouper, a beautiful red-tipped sea anemone (*Condylactis gigantea*) of large size expands its cream-colored, petal-like tentacles above a scarlet body. The sea anemones are closely related to coral polyps, but, unlike them, are incapable of building a stony skeleton.

At the extreme right of the group, a series of great domelike heads of brain coral (*Mœandra*) and purple sidereal coral (*Siderastrea*) rise in a clustered terrace of massive outline. Among them tower post-like pinnacles of tree-stump coral (*Dendrogyra cylindrus*), with meandriform patterns completely covering their shafts. Butterfly fishes flutter about, their light delicacy in strong contrast to the massive rotundity of the coral heads.

The loosely branching antlers of staghorn coral (*Acropora cervicornis*) grow out from the narrow crevices between the heads, their sharp points menacing like *chevaux-de-frise*. Immediately before one's eyes, the striking color pattern and unbelievable form of the queen trigger fish (*Balistes vetula*) startle the gaze of the onlooker. Various individuals are differently colored, but all are equally surprising.

STARTLING COLOR COMBINATIONS

The most brilliant combination starts with velvety bright green on the upper part, shading into equally bright purple below. The lower part of the face may be pink or yellow, and two extraordinarily brilliant blue streaks are slashed across the face. Radiating irregular lines of black outlined with cream dart in all directions like lightning streaks from the very bright eyes with their little, black, beadlike pupils. The body of the fish is so narrow that when it turns toward you it seems almost to disappear. Its little, absurdly puckered mouth is furnished with white, close-set teeth. The fish is not shy, but will swim directly up to your helmet and peer in at you, moving its pursed up mouth as if it were trying to kiss you. If you try to grab at it with your hands you find it always just beyond your grasp.

Above it is another surprise, — a fish that we often see nosing about the reef, always singly. It is the equally absurd trumpet fish (*Aulostomus maculatus*). It grows to a yard or more in length, and is equipped with a ridiculous elongated snout, flattened vertically with a small mouth at the extreme end which is always in motion. It has a pulled-out caricature of a horselike face with small eyes set far back. The paired fins are very small, — almost insignificant, but the vertical dorsal and anal fins are broad and set so far back on the body as to seem about to slide off on to the fan-shaped almost arrow-headed tail. The color-pattern is quite as surprising. It is faintly suggestive of a Scotch plaid, being composed of vertical brown bands crossing longitudinal yellow stripes at right angles, against a light tan background. Small black dots are sprinkled over this array in longitudinal rows. As the fish progresses, it may expand its mouth like a trumpet, or the whole snout will droop in elephantine fashion. Sometimes it swims nearly upright, with head either up or down.

It is refreshing to turn from this out-

(*Left*) *The weird trumpet fish, with its elongate, extensible snout and Zeppelin-like body, floats slowly through a school of spotted hinds*

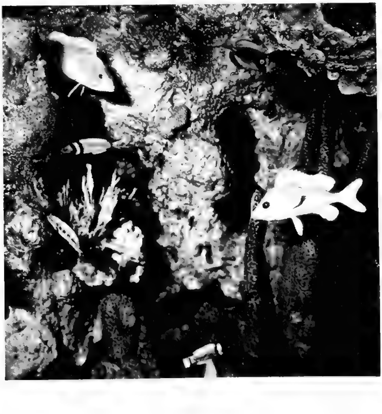
(*Below*) *A cluster of tube-building marine worms expands purple, flower-like heads on the side of an eroded coral pedestal*

A green moray lurks within an arched cavern, ready to attack any passing creature with its array of needle-sharp teeth

(Below) Around a fanlike elkhorn flit banded butterfly fish, slippery dicks, female and young blueheads. A surgeon fish swims below them

(Above) Gnarled, interlacing branches of the elkhorn coral form dense forests of stone trees rising to the water surface from the sea floor

(Below) A gray snapper (upper left) darts down among the smaller blueheads. A blue-striped grunt swims in from the right



Queen

Trigger

Fish

Its striking colors and unbelievable form startle the observer. Bright green blends into equally bright purple. Part of the face is yellow, slashed by blue lines of the utmost brilliancy. Lightning-like streaks of black and yellow radiate from the eyes

landish affair to the school of more normal looking rock hinds (*Epinephalus adscensionis*) swimming near and above it, their bodies patterned with reddish, oval spots.

The trumpet fish is headed toward a growth of sea feathers. Let us look in the same direction downward to the right and behind the beautifully symmetrical growth of elkhorn coral with the clustered sea fans at its base. Peering in here carefully, we see two huge, rainbow parrot-fishes (*Pseudoscarus guacamaia*) lurking in the shadows. Their name is quite appropriate, for they have conspicuous blue teeth, continuing the shape of the head in parrot-like profile. The scales of the hinder portion of the body are green edged with brown, while the forward part is of variable reddish brown. Let us compare them with the blue parrot-fish (*Scarus cæruleus*), in the cave at the extreme right of the group. These fish are uniformly blue, though in some individuals this may shade into dark indigo.

The conspicuous teeth are white and are very powerful grinders. I have watched these creatures through the windows of my helmet, as they swam out of their cavern and nosed about the rocky surface flanking it. They would actually bite off pieces of the limestone, grind them between their powerful teeth, presumably to get at the boring worms, sponges, and other nutriment permeating the porous substratum. After the rock was ground to powder, they would eject it from their mouths, and I could see the clouds of pulverized limestone rising toward the surface.

A school of gray snappers (*Lutianus griseus*) edges out of the lower part of the cave below the blue parrots and turns to the right where blue tangs or surgeon fish (*Acanthurus cæruleus*) are circling uncertainly. These are vertically flattened fishes, rounded in outline. Their color is a chocolate-brown with fine blue lines running through it. The edge of the dorsal fin is lined with blue. Their name is derived from the sharp curved lancet on either side of the peduncle of the tail. This may be erected and will lacerate the hand to such an extent that there would be no doubt about its capacity for blood-letting.

Blue-striped grunts (*Hæmulon sciurus*) are swimming out from the extreme lower right of the group, past posts of *Dendrogyra* coral, their flat-nosed bodies adorned with a striking pattern of narrow, alternating blue and yellow stripes. The blue lines often gleam as the fish turns in the sunlight, so as to appear almost iridescent. Above the ledge where they are swimming is an obliquely sloping shelf capped with encrusting green brain coral (*Mæandra viridis*), from which a small forest of gorgonian sea bushes is growing, partly obscuring the entrance to the Cavern of the Blue Parrotfishes. A closely packed school of spotted hinds (*Epinephalus guttatus*) swims downward past the clump, keeping in ordered phalanx as though it were perilous to direct their course past the den of the larger fish.

A MARINE KALEIDOSCOPE

Before we turn away from the group, our eyes catch a flash of color, and we stoop to examine at close range a squadron of squirrel-fishes (*Holocentrus ascensionis*) sliding past in front of the cluster of mushroom-like orb corals already mentioned. These little fishes are brilliant scarlet in color with darker stripes running the length of their body. Their huge, dark-red eyes seem out of all proportion to their size.

These are only a few of the multitudinous fishes ordinarily associated with a Bahaman coral reef. The entire number of species recorded from the Bahamas mounts up to more than a thousand. The Coral Reef Group is carefully planned to display a balanced association of reef-life, occurring at a definite locality, with the number of species likely to be noticed readily during an average trip to the sea bottom if one were observant and had time to take stock of his surroundings. It must be remembered that the scene would be changing constantly, and the observations of successive visits to the same locality would never be identical. Then, as we moved from place to place along the same reef, every location would be different from the rest. The character and arrangements of the coral growths and associated forms would change kaleidoscopically, one factor becoming dominant in a given region, while in another place it would be of secondary importance.

ALPHABETICAL GUIDE

TO

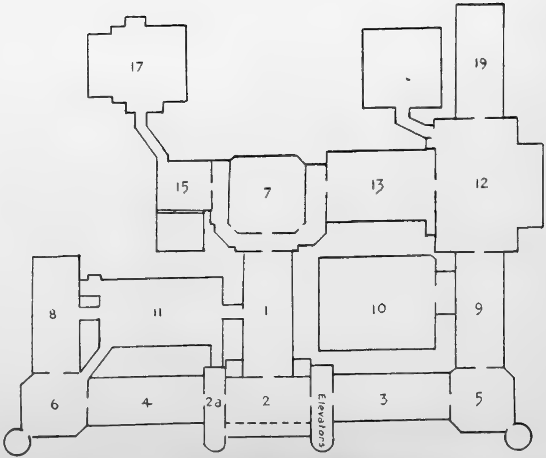
THE BIRD EXHIBITS

IN THE

American Museum of
Natural History

Guide Leaflet Series No. 90

NEW YORK CITY
JULY, 1935



West Seventy-Seventh Street
Floor Plan American Museum of Natural History

THE Museum's bird exhibits are displayed in halls 1, 2, and 2a of the second and third floors in the central part of the building. They include many habitat groups showing birds in their natural surroundings, nest and subject groups, a systematic collection of the leading types of birds and their skeletons arranged to show the most approved classification, and about 10,000 birds arranged according to the Faunal Regions they inhabit.

To acquaint you with the nature and extent of these exhibits and to tell you where they may be found, this alphabetical guide to them has been made. When you have learned the Museum geography and the meaning of the location symbols here used, it is believed that you will have no difficulty in finding your way to any subject listed in this guide.

This leaflet does not pretend to be a complete guide to the bird exhibits; to include them all would require a volume. It lists only all the groups, large and small, some places and subjects, the various collections, as a whole, and the more widely known species. When a bird is not found entered under its specific title, look for it under its family name. Thus Hermit Thrush will be found under "Thrushes, North American, **II**, **1**, L-3": meaning floor **II**, hall **1**, case L, section 3.

ALPHABETICAL GUIDE

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American Museum of
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NEW YORK CITY
JANUARY, 1937
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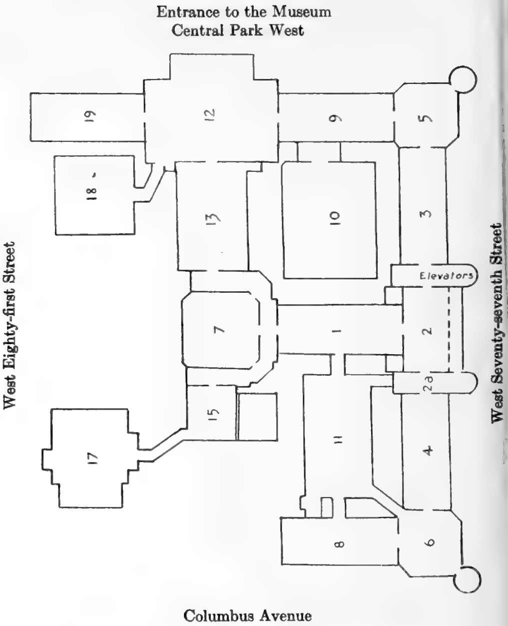

Floor Plan American Museum of Natural History

THE Museum's bird exhibits are displayed in the corridor of floor **I** of the Roosevelt Memorial and in halls **1** and **2** of floors **II** and **III** in the central part of the building. They include many habitat groups showing birds in their natural surroundings, nest and subject groups, a systematic collection of the leading types of birds and their skeletons arranged to show the most approved classification, and about 10,000 birds arranged according to the Faunal Regions they inhabit.

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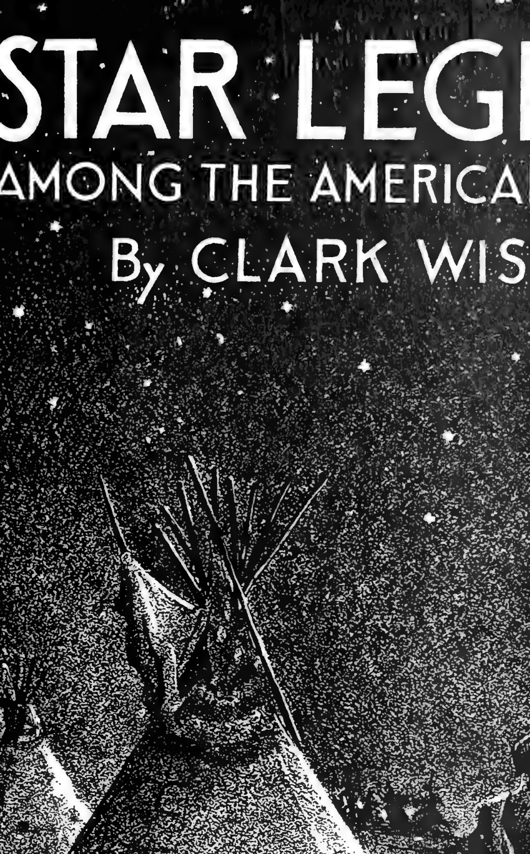
STAR LEG
AMONG THE AMERICA
By CLARK WIS

This frontispiece is reproduced from a mural painted by Charles R. Knight for the Hayden Planetarium.

The mural depicts the Sun-God in pursuit of the Moon-Goddess. The Old Man, another Indian mythological character, is seen sitting on the peak of a mountain rising out of the water. He is watching for the return of four creatures, the duck, the beaver, the otter and the muskrat, whom he has sent to the bottom of the sea to bring clods of earth to use as building material in his task of forming the world. The muskrat was successful and is shown rising to the surface, while his companions, who failed and perished, may be seen sinking.

At the top of the picture is shown a night sky with two constellations: at the left are the six brothers and one little sister—the "big dipper," and at the right are the six brothers (huntsmen) with their three dogs—the Pleiades. Between the constellations lies the Milky Way.

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STAR LEGENDS
Among the American Indians

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☆

By
CLARK WISSLER
Curator of Anthropology

The American Museum of Natural History
Guide Leaflet Series No. 91
NEW YORK, N. Y.

1936

CONTENTS

INTRODUCTION

IT HAS been said that man first began to study the things farthest away from him and so astronomy is the oldest science and psychology the most recent. Perhaps the heavenly bodies were by far the greatest mysteries and appealed to primitive man as the most desirable forms of existence; anyway, in many lands and ages the dead are believed to become stars. Our Indians gave a great deal of attention to the heavens as revealed in the many beautiful stories told around their camp fires. So it seems peculiarly appropriate that this Planetarium should record a few masterpieces in Indian creative literary art.

Mr. Charles R. Knight, who conceived and executed the murals in the Planetarium, chose his themes from a series of star myths known to the Blackfoot Indians of Montana. In the following pages we print English versions of these myths in order that the reader may come to realize that what Mr. Knight did was to set himself the task of illustrating a few of these aboriginal classics. It is hoped that the reader may sense the simple beauty in the narratives which inspired the artist to execute these appealing murals.

FOREWORD

THE star myths in this booklet were narrated to the writer by Wolf-head, a Blackfoot Indian. An oral translation was made by an English-speaking Indian which the writer recorded as given. The translation follows closely the style of the narrator and the translator, we hoping that in this way something of the personality of the narrator might be retained. Wolf-head understood that these myths would be published eventually and as he proceeded we realized that he was making the artistic effort of his life. The story of the Twin Brothers was the last and evidently regarded by him as his masterpiece. The reader may prefer the simpler tale of the Fixed Star or perhaps Scar-Face, but to one understanding what Blackfoot life was like forty or more years ago, the Twins will make a strong appeal. George Bird Grinnell, Walter McClintock and J. W. Schultz have published interesting books about the Blackfoot Indians.

These myths were recorded in 1903. Even then Wolf-head was an elderly man, his death occurring two years later. No Indian of his age knew the date of his birth, as there were no true calendars, but Wolf-head believed he was born about 1840. So he, as a young man, went to war, hunted buffalo and lived the life of an aboriginal before his tribe was settled upon a reservation.

C. W.

STAR LEGENDS among the American Indians

☆ ☆ ☆

The Sun and the Moon

THE central picture represents the artist's interpretation of a myth explaining how the sun and moon came to be. One version of the myth states that the sun was the brother and the moon the sister in a family of the long ago. Often they quarreled. Upon one occasion the sister was so outraged over the treatment she received at the hands of her brother, that she grasped a burning stick from the house fire and rushed up through the smoke hole of the tipi. The brother shouted that she could not escape him in that way, caught up a larger fire brand and followed in pursuit. So they continue to this day, the moon with the fainter light moving across the sky at night, the sun with his great fire brand still pursuing, causing the day.

The theme of this myth is not peculiar to the Blackfoot Indians but was spread among Indian tribes ranging from Cape Cod to Alaska. The details of the myth vary as in all unwritten literature but the essentials of the plot are the same. The Blackfoot Indians, however, preferred to look upon the Sun and Moon as their chief deities. The Sun was the most sacred and powerful of all and the Moon was his wife. They lived in a tipi in the sky country. So it is fitting that the Sun and the Moon should occupy the center of the mural and dominate the other parts of the painting.

The Creation of the Earth

THE scene beneath the rainbow on the left represents a Culture-Hero of the Blackfoot Indians known as Napi or the Old Man. He is not only credited with making the earth as we now see it, but the people and everything else in the world. He is called a Culture-Hero because before he left the world he taught the people how to live and to order their daily lives. The earliest record of this Blackfoot conception is a statement in the diary of Alexander Henry under the date of 1809. Henry was the head of a large fur-trading company operating posts in all parts of the northern plains country, especially in Canada. He says that from one of the Blackfoot Chiefs visiting his post he obtained the following:

At first the world was one body of water inhabited by only one great white man and his wife, who had no children. This man, in the course of time, made the earth, dividing the waters into lakes and rivers, and formed the range of the Rocky Mountains; after which he made the beasts, birds, fishes, and every other living creature.

A later version collected by the writer contains the following plot:

A great flood came and the waters began to rise over the hills. The Old Man was running from one height to another to escape it. At last he climbed to the top of the highest mountain. Here he was joined by four of the

animals, beaver, otter, duck and muskrat. The water rose almost to the top of the mountain but could go no farther for the Old Man was too powerful. For a long time he waited but the waters did not recede. At last the Old Man said that if he had some mud, even a speck of it, he could create dry land. Then he ordered the beaver to dive to the bottom but after a long time his lifeless body floated to the surface. Next the otter tried but with the same tragic result. Then the Old Man sent the duck down but it came up unconscious. It was now the turn of the muskrat. He was gone a very long time and when he did appear he, too, was unconscious but held fast in his front paws the precious particle of mud. The Old Man put the mud on the palm of his hand and blew upon it. It began to grow bigger and bigger until it spread out upon and into the water, finally forming the land as we see it to-day. Then he made the plants, then all the living things.

The rainbow does not have a place in this myth but the Blackfoot speak of it in mythical terms. Thus among its numerous names are Rain's Hat, Old Man's Fish Line, Lariat, and so forth. It is, therefore, appropriate that the artist should paint this brilliant arch over the Old Man creating the world. We say creating the earth but that is not quite right. Not only the Blackfoot Old Man, but all similar characters in American Indian mythology, are really transformers. They take things as they find them and merely change them into the forms known to us. They do not make something out of nothing.

The Six Brothers

THE Blackfoot speak of the Pleiades as the Six Brothers and again as the Bunched Stars. In some versions of this myth the boys take their dogs with them to the sky land so in the mural we see the stars in position and the shadowy forms of the six boys and three dogs.

The version of this myth, narrated to us by Wolf-Head, ran thus:

In a camp of our people there was a family of six boys. Their parents were very poor. Every spring the people went out to hunt for buffalo. At this time of the year, the buffalo-calves are red, and their skins are much desired for children's robes. Now as the parents of these children were very poor and not able to do much hunting, these boys had to wear brown robes or those made of old buffalo-skins. As the children grew up, they were constantly reminded of the fact that they had no red robes. The other children of the camp sometimes made fun of them because of this. So one day one of the boys said to his brothers, "Why is it that we never get any red robes? If we do not get any next spring, let us leave the camp and go up into the sky." Then the boys went out to a lonely place to talk the matter over. Finally they agreed that, if they did not get red robes in the following spring, they would go up to the sky country. The spring hunting-season passed, but no red robes came to the boys. Then the oldest brother said, "Now I shall take you all up to the sky." The fourth brother said, "Let us also take all the water away from the people, because they have been bad to us." Another brother said, "We must take our dogs with us.

Then the oldest brother took some weasel-hair, placed a little on the backs of his brothers and upon their dogs. Then he took another bunch of hair, put it first into his mouth, then rubbed it on his palm. "Now shut your eyes," he said. Then he blew the weasel-hair up, and, when the brothers opened their eyes, they found themselves in the house of the Sun and Moon. The Sun, who was an old man, and the Moon, who was his wife, said, "Why have you come?" "We left the earth," said the oldest brother, "because the people never gave us red robes. All the other children had red robes to wear, but we had only brown ones. So we have come to you for help." "Well," said the Sun, "what do you want?" The fourth brother

said, "We should like to have all the water taken away from the people for seven days." Now the Sun made no answer to this; but the Moon took pity on the poor boys and said, "I will help you; but you must stay in the sky." The Moon pitied the boys so much that she cried. She asked the Sun to aid her in taking away the water from the people; but the Sun made no answer. She asked him seven times. At last he promised to aid her.

Now the next day on the earth was very hot. The water in the streams and lakes boiled, and in a short time it all evaporated. The next night was very warm and the moonlight strong. When the water was gone, the people in the camp said, "Let us take two dogs with us out to the river-bed." When they came to the bank of the river, the two dogs began to dig a hole in the side of the bank. When they had dug a long time, water came out of the hole like a spring. This is the way springs were made. Even to this day, all the people have great respect for their dogs because of this. The days were so hot that the people were forced to dig holes into the hills and crawl into them. They would have died, if they had remained on top of the ground. When the water in the springs gave out, the dogs made other springs. Now the leader of the dogs was a medicine-dog. He was old and white. On the seventh day he began to howl and look at the sky. He was praying to the Sun and the Moon. He explained to the Sun and Moon why it was that the boys got no red robes. He asked them to take pity on the dogs below. (This is why dogs sometimes howl at the moon.) On the eighth day the Sun and Moon gave the people rain. It was a great rain, and it rained for a long time.

The six boys remained in the sky, where they may be seen every night. They are the Bunched Stars (Pleiades).

The Seven Brothers

THE Great Dipper has always intrigued the human mind. The milky way which was used by the artist as a part of the decoration is rarely the subject of a myth but often spoken of as the sky-trail and sometimes as the wolf-trail. The Blackfoot did not know that the milky way is composed of stars, since they had no telescopes, hence their explanation is natural enough.

A young woman had seven brothers and a little sister. One of the brothers was still too young to go about alone, so the little sister carried him upon her back. Their parents were dead and since they had no relations they lived alone.

One day the little sister said to the older sister, "Now you be a bear and we will go out into the brush to play." The older sister agreed to this, but said, "Little sister, you must not touch me over my kidneys." So the big sister acted as a bear, and they played in the brush. While they were playing, the little sister forgot what she had been told, and touched her older sister in the wrong place. At once she turned into a real bear, ran into the camp, and killed many of the people. After she had killed a large number, she turned back into her former self. Now, when the little sister saw the older run away as a real bear, she became frightened, took up her little brother, and ran into their lodge. Here they waited, badly frightened, but were very glad to see their older sister return after a time as her true self.

Now the older brothers were out hunting, as usual. As the little sister was going down for water with her little brother on her back, she met her six brothers returning. The brothers noted how quiet and deserted the camp seemed to be. So they said to their little sister, "Where are all our people?" Then the little sister explained how she and her sister were playing, when the elder turned into a bear, ran through the camp, and killed many people. She told her brothers that they were in great danger, as

their sister would surely kill them when they came home. So the six brothers decided to go into the brush. One of them had killed a jack-rabbit. He said to the little sister, "You take this rabbit home with you. When it is dark, we will scatter prickly-pears all around the lodge, except in one place. When you come out, you must look for that place, and pass through."

When the little sister came back to the lodge, the elder sister said, "Where have you been all this time?" "Oh, my little brother mussed himself and I had to clean him," replied the little sister. "Where did you get that rabbit?" she asked. "I killed it with a sharp stick," said the little sister. "That is a lie. Let me see you do it," said the older sister. Then the little sister took up a stick lying near her, threw it at the rabbit, and it stuck in the wound in his body. "Well, all right," said the elder sister. Then the little sister dressed the rabbit and cooked it. She offered some of it to her older sister, but it was refused: so the little sister and her brother ate all of it. When the elder sister saw that the rabbit had all been eaten, she became very angry, and said, "Now I have a mind to kill you." So the little sister arose quickly, took her little brother on her back, and said, "I am going out to look for wood." As she went out, she followed the narrow trail through the prickly-pears and met her six brothers in the brush. Then they decided to leave the country, and started off as fast as they could go.

The older sister, being a powerful medicine-woman, knew at once what they were doing. She became very angry and turned herself into a bear. The prickly-pears stopped her for a time but at last she found the trail and started in pursuit. Soon she was about to overtake them, when one of the boys tried his power. He took a little water in the hollow of his hand and sprinkled it around. At once it became a great lake between them and the bear. Then the children hurried on while the bear went around. After a while the bear caught up with them again, when another brother threw a porcupine-tail (a hairbrush) on the ground. This became a great thicket; but the bear forced its way through, and again overtook the children. This time they all climbed a high tree. The bear came to the foot of the tree, and, looking up at them, said, "Now I shall kill you all." So she took a stick from the ground, threw it into the tree and knocked down four of the brothers. While she was doing this, a little bird flew around the tree, calling out to the children, "Shoot her in the head! Shoot her in the head!" Then one of the boys shot an arrow into the head of the bear, and at once she fell dead. Then they came down from the tree.

Now the four brothers were dead. The little brother took an arrow, shot it straight up into the air, and when it fell one of the dead brothers came to life. This he repeated until all were alive again. Then they held a council, and said to each other, "Where shall we go? Our people have all been killed, and we are a long way from home. We have no relatives living in the world." Finally they decided that they preferred to live in the sky. Then the little brother said, "Shut your eyes." As they did so, they all went up. Now you can see them every night. The little brother is the North Star. The six brothers and the little sister are seen in the Great Dipper. The little sister and the eldest brother are in a line with the North Star, the little sister being nearest it because she used to carry her little brother on her back. The other brothers are arranged in order of their age, beginning with the eldest. This is how the seven stars (Great Dipper) came to be.

* * *

We heard different interpretations as to the position of the sister and her little brother. The foregoing is the way the narrator told it to us and is the version used by the artist; but we heard another narrator say that the sister is Mizar in the handle of the dipper and that the little brother is the small star near the

sister but not a part of the handle. This would be consistent. Again another said that Mizar was the little brother and the star near-by was the sister. Such variations are common in folk lore. The star at the end of the handle is spoken of as the Last Brother. The revolving of the dipper around the North Star served the Blackfoot as a night clock, its position indicating the passing of time, so one might say, "Now the Last Brother is pointing downward," etcetera.

The Thunder Bird and the Aurora

This completes the myths depicted in the mural but at the sides of the central picture are two minor panels representing the Aurora and the Thunder Bird.

The panel on the left represents the aurora borealis. Its prominence in northern latitudes restricts its tribal distribution. The version used by the artist is that the aurora is the flickering light of a great campfire around which people are dancing, usually supernatural people. Thus some of the Blackfoot Indians say when they see the aurora, "The sky people of the North are dancing."

The panel on the right represents a common Indian notion of thunder and lightning. The power of "the thunderer" impressed the Indian perhaps more than any other heavenly phenomenon, and "the thunderer" was often conceived as a great bird, probably because birds are able to soar in the heavens. There are few well-formulated stories about the Thunderer but he is often referred to in such narratives. Sometimes the lightning is interpreted as the flashing of his eyes; again as the stroke of his wing or his war-club. Warriors often prayed to him for power to strike their enemies.

Other Star Myths

THE Blackfoot Indians have other myths about the stars. In fact their belief was that every star was once a human being. They thought of the stars as not fixed in number, but as ever increasing, for when any of their people died they believed that their spirits ascended to become stars. A sorrowing mother would watch the sky for what she believed to be a new star and finding one would say, "Now my child is looking down upon me." It was a beautiful belief, that when one walked abroad at night his relatives and all the old ones were looking down upon him with kindness and sympathy.

So it is not strange that the most prominent stars in the heavens were given personal names. As illustrations we add a few more myths, most of which were known to many other Indian tribes as well as to the Blackfoot.

Incidentally, we remark that many stars had symbolic names without an associated story, though it is possible there was once a story later lost to memory. Thus, Mars was the Big Fire Star; Venus the Day Star because it was occasionally seen during the day; a comet was "a star feeding"; and so on.

The Fixed Star

BLACKFOOT narrators sometimes designated the North Star as the Fixed Star. In the story of the Seven Stars it was said to be one of the brothers, though not always so considered; however, myths need not be consistent, for they are literature, and even the most devout Blackfoot recognized the legitimacy of these different versions. For example, we now give a story accounting for the North Star in a different way. Incidentally, we note that this story is found among the mythological collections from many tribes throughout the United States. Everywhere it was a favorite and so is an Indian literary classic.

* * *

One summer night when it was very hot inside the lodge, two young women went outside to sleep. They woke up before daylight and were looking up at the sky, when one of them saw the Morning Star. She said to her companion, "That is a very bright star. I should like him for a husband." She soon forgot what she had said. In a few days these two young women went out from the camp to gather wood. When they had made up their packs and were drawing them up on their shoulders with the pack-straps, the strap broke that belonged to the girl who said she wished the Morning Star for her husband. Every time she made up her bundle and raised it to her back, the strap would break. Her companion, who was standing by her side with her pack on her shoulders, began to grow weary. She said, "I shall go on with my load: you can follow."

When the young woman was left alone, and had made up her bundle again, a handsome young man came out of the brush. He wore a fine robe made of beaver-skins, and had an eagle-plume in his hair. When the young woman started to go on, he stepped in front of her. Whichever way she turned, he headed her off. Finally she said to him, "Why do you head me off?" The young man replied, "You said you would take me for your husband." "No," said the young woman, "you must be mistaken. I never had anything to do with you. I do not know you. "I am the Morning Star," said the stranger, "and one night, when you looked up at me, you said that you wished me for a husband. Now I have come for you." "Yes, I did say that," said the young woman. So she consented to go away with him. Then Morning Star put an eagle plume in her hair, and told her to shut her eyes. Then they went up into the sky.

Now the Sun was the father of the Morning Star and the Moon was his mother. When they came into the lodge, Morning Star said to his parents, "I have brought a wife with me." The parents were pleased with what their son had done. Moon gave the young wife four berries and a few drops of water in a little shell. These were given to her to eat and to drink. Though the young woman was very hungry, she could neither eat all of the berries nor drink all of the water, because these berries were all the food there was in the world and the shell contained all the water there was in the ocean.

After a time, Moon said to her daughter-in-law, "Now I shall give you a root-digger, and you may go out to dig roots; but you are not to dig that big turnip there, because it is sacred. So the young woman went about the sky country digging roots for their food. She often looked at that fine large turnip growing there, and was curious to know why she was forbidden to dig it up. In course of time she gave birth to a child. One day, when it was old enough to sit alone, she said to herself as she went out to dig roots, "Now no one will know about it if I do dig it up." So she stuck her digging-stick into the ground under the turnip; but, when she tried to raise it, the stick would not move. When she found that she could not get the stick out, she began to cry. Then two large white cranes flew down; one was a male and the other a female. The young woman prayed to them for help to get her root-digger out of the ground. Then the Crane-Woman said, "When I married I was true to my vow. I never had anything to do with any other man than my husband. It is because of this that I have power to help you. Your mother gave you this digging-stick. Now I shall teach you the songs that go with it." Then Crane-Woman burned incense, took the hands of the woman into her own, and, while she sang the songs, placed them upon the digging-stick. Then Crane-Woman pulled out the stick, and, marching around in the direction of the sun, made three movements toward the turnip, and with the fourth dug it out. Now the young woman took the digging-stick and the turnip home with her. When they saw what she had, they reprimanded her. Morning Star said to her, "What did you see when you dug out this turnip?" The woman replied, "I looked down through the hole and saw the earth, the trees,

the rivers, and the lodges of my people."

"Now," said Morning Star, "I cannot keep you any longer. You must take the boy with you and go back to your people; but when you get there you must not let him touch the ground for two-seven (fourteen) days. If he should touch the ground before that time, he will become a puff-ball (a fungus), go up as a star, and fit into the hole from which you dug the turnip. He will never move from that place, like the other stars, but will always be still."

Sun said to her, "I shall call in a man to help you down to the earth." After a while a man came with a strong spiderweb, to one end of which he tied the woman and the boy, and let them down through the hole from which the turnip was taken. The woman came down over the camp of her own people. The young men of the camp were playing at the wheel-game. One of them happened to look up into the sky, where he saw something coming down. Now this young man had very poor eyes, and, when he told his companions that something was coming down from the sky, they looked, and, seeing nothing, made sport of him. As he still insisted, they, in derision, threw dirt into his eyes. But after a while they, too, saw something coming down from the sky. As the woman reached the ground in the centre of the camp, some one, recognizing her, called out. "Here is the woman who never came back with her wood." Then all her friends came out to meet her, and her mother took her home.

Now, before the woman left the sky, Morning Star told her, that, since she had made one mistake in digging up the turnip, she would no doubt make another mistake, and allow the child to touch the ground before the time was up. So he advised her to make the sign of the Morning Star on the back of her lodge, so that she might be reminded daily of her duty. (The doors of the lodges at that time faced the sun, and the sign of the Morning Star was to be made upon the back of the lodge, because he always travels on the other side from the sun.)

The young woman kept careful watch over the boy for thirteen days. On this day her mother sent her out for water. Before going out, the young woman cautioned her mother to keep the child upon the bed, and not allow him to touch the ground. Now the grandmother was not so careful, because she did not understand the reason for watching the child; and while her back was turned he crawled out upon the ground. When she saw him, she caught him up, putting him back on the bed as quickly as she could. This seemed to make the child angry, for he pulled the robe up over himself. The grandmother paid no further attention to him.

Now, when the boy's mother came back, she looked around, and said, "Where is my child?" "Oh, he covered himself up with a robe," said the grandmother. The young mother rushed to the bed, pulled back the robe, and found nothing but a puff-ball (fungus). She caught this up, and carried it in her bosom all the time.

That evening when the stars came out, she looked up into the sky. A new star stuck in the hole from which she pulled the turnip. Then she knew what had become of her child.

This is the way the Fixed Star came to be.

After this the woman painted circles around the bottom of her lodge to represent the puff-ball, or the Fallen Star (the one that came down). She had already painted the Morning Star on the back of her lodge. This is why the people paint their lodges in the way that you see them. Also this woman brought down the sacred turnip and the digging-stick. Crane-Woman taught her the songs that go with them and their use in the sun-dance. This was the beginning of the medicine-woman (leader in the sun-dance).

* * *

The Blackfoot believe that the puff-ball fungus is what is left after a star falls. (Probably suggested by the genus of puff-balls, called by botanists *Geasters* or earth-stars, having

double walls, the outer one of which bursts open and spreads out, presenting the appearance of a conventional star.) The narrator is using a literary touch in referring to the fact that the child came from the sky and so was a fallen star. The large tipi in the Plains Indian Hall of the Museum has circular spots around its base representing these "fallen stars" lying on the ground. At the top the Seven Stars, the Six Brothers and the Morning Star are represented. If the reader will visit this tipi with this charming legend in mind, he will catch some of the spirit of the Blackfoot Indian woman who made the skin cover of the tipi and decorated it. She, like the painter of the mural on the Planetarium wall, was interpreting in form and color a legend of the olden time.

Blood-Clot, or Smoking-Star

ONCE there was an old man and woman whose three daughters married the same young man. The old people lived in a lodge by themselves. The young man was supposed to hunt buffalo, and feed them all. Early in the morning the young man invited his father-in-law to go out with him to kill buffalo. The old man was then directed to drive the buffalo through a gap where the young man stationed himself to kill them as they went by. As soon as the buffalo were killed, the young man requested his father-in-law to go home. He said, "You are old. You need not stay here. Your daughters can bring you some meat." Now the young man lied to his father-in-law; for when the meat was brought to his lodge, he ordered his wives not to give meat to the old folks. Yet one of the daughters took pity on her parents, and stole meat for them. The way in which she did this was to take a piece of meat in her robe, and as she went for water drop it in front of her father's lodge.

Now every morning the young man invited his father-in-law to hunt buffalo: and, as before, sent him away and refused to permit his daughters to furnish meat for the old people. On the fourth day, as the old man was returning, he saw a clot of blood in the trail, and said to himself, "Here at least is something from which we can make soup." In order that he might not be seen by his son-in-law, he stumbled, and spilt the arrows out of his quiver. Now, as he picked up the arrows, he put the clot of blood into the quiver. Just then the young man came up and demanded to know what it was he picked up. The old man explained that he had just stumbled, and was picking up his arrows. So the old man took the clot of blood home and requested his wife to make blood-soup. When the pot began to boil, the old woman heard a child crying. She looked all around, but saw nothing. Then she heard it again. This time it seemed to be in the pot. She looked in quickly, and saw a boy baby: so she lifted the pot from the fire, took the baby out and wrapped it up.

Now the young man, sitting in his lodge, heard a baby crying, and said, "Well, the old woman must have a baby." Then he sent his oldest wife over to see the old woman's baby, saying, "If it is a boy, I will kill it." The woman came in to look at the baby, but the old woman told her it was a girl. When the young man heard this, he did not believe it. So he sent each wife in turn; but they all came back with the same report. Now the young man was greatly pleased, because he could look forward to another wife. So he sent over some old bones, that soup might be made for the baby. Now, all this happened in the morning. That night the baby spoke to the old man, saying, "You take me up and hold me against each lodge-pole in succession." So the old man took up the baby, and, beginning at the door, went around in the direction of the sun, and each time that he touched a pole, the baby became larger. When halfway around, the baby was so heavy that the old man could hold him no

longer. So he put the baby down in the middle of the lodge, and, taking hold of his head, moved it toward each of the poles in succession, and, when the last pole was reached, the baby had become a very fine young man. Then this young man went out, got some black flint (obsidian) and, when he got to the lodge, he said to the old man, "I am the Smoking-Star. I came down to help you. When I have done this, I shall return to the sky."

Now, when morning came, Blood-Clot (the name his father gave him) arose and took his father out to hunt. They had not gone very far when they killed a scabby cow. Then Blood-Clot lay down behind the cow and requested his father to wait until the son-in-law came to join him. He also requested that he stand his ground and talk back to the son-in-law. Now, at the usual time in the morning, the son-in-law called at the lodge of the old man, but was told that he had gone out to hunt. This made him very angry, and he struck at the old woman, saying, "I have a notion to kill you." So the son-in-law went out.

Now Blood-Clot had directed his father to be eating a kidney when the son-in-law approached. When the son-in-law came up and saw all this, he was very angry. He said to the old man, "Now you shall die for all this." "Well," said the old man, "you must die too, for all that you have done." Then the son-in-law began to shoot arrows at the old man, and the latter, becoming frightened, called on Blood-Clot for help. Then Blood-Clot sprang up and upbraided the son-in-law for his cruelty. "Oh," said the son-in-law, "I was just fooling." At this Blood-Clot shot the son-in-law through and through. Then Blood-Clot said to his father, "We will leave this meat here, it is not good. Your son-in-law's house is full of dried meat. Which one of your daughters helped you?" The old man told him that it was the youngest. Then Blood-Clot went to the lodge, killed the two older women, brought up the body of the son-in-law, and burned them together. Then he requested the younger daughter to take care of her old parents, to be kind to them, etc. "Now," said Blood-Clot, "I shall go to visit the other Indians."

So he started out, and finally came to a camp. He went into the lodge of some old women, who were very much surprised to see such a fine young man. They said, "Why do you come here, among such old women as we? Why don't you go where there are young people?" "Well," said Blood-Clot, "give me some dried meat." Then the old women gave him some meat, but no fat. "Well," said Blood-Clot, "you did not give me the fat to eat with my dried meat." "Hush!" said the old women. "You must not speak so loud. There are bears here that take all the fat and give us the lean, and they will kill you, if they hear you." "Well," said Blood-Clot, "I will go out tomorrow, do some butchering, and get some fat." Then he went out through the camp, telling all the people to make ready in the morning, for he intended to drive the buffalo over the cliff.

Now there were some bears who ruled over this camp. They lived in a bear-lodge (painted lodge), and were very cruel. When Blood-Clot had driven the buffalo over, he noticed among them a scabby cow. He said, "I shall save this for the old women." Then the people laughed, and said, "Do you mean to save that poor old beast? It is too poor to have fat." However, when it was cut open it was found to be very fat. Now, when the bears heard the buffalo go over the drive, they as usual sent out two bears to cut off the best meat, especially all the fat; but Blood-Clot had already butchered the buffalo, putting the fat upon sticks. He hid it as the bears came up. Also he had heated some stones in a fire. When they told him what they wanted, he ordered them to go back. Now the bears were very angry, and the chief bear and his wife came up to fight, but Blood-Clot killed them by throwing hot stones down their throats. Then he went down to the lodge of the bears and killed all, except one female who was

about to become a mother. She pleaded so pitifully for her life, that he spared her. If he had not done this, there would have been no more bears in the world. The lodge of the bears was filled with dried meat and other property. Also all the young women of the camp were confined there. Blood-Clot gave all the property to the old women, and set free all the young women. The bears' lodge he gave to the old women. It was a bear painted lodge.

"Now," said Blood-Clot, "I must go on my travels." He came to a camp and entered the lodge of some old women. When these women saw what a fine young man he was, they said, "Why do you come here, among such old women? Why do you not go where there are younger people?" "Well," said he, "give me some meat." The old women gave him some dried meat, but no fat. Then he said, "Why do you not give me some fat with my meat?" "Hush!" said the women, "you must not speak so loud. There is a snake-lodge here, and the snakes take everything. They leave no fat for the people." "Well," said Blood-Clot, "I will go over to the snake-lodge to eat." "No, you must not do that," said the old women. "It is dangerous. They will surely kill you." "Well," said he, "I must have some fat with my meat, even if they do kill me." Then he entered the snake-lodge. He had his white rock knife ready. Now the snake, who was the head man in this lodge, had one horn on his head. He was lying with his head in the lap of a beautiful woman. He was asleep. By the fire was a bowl of berry-soup ready for the snake when he should wake. Blood-Clot seized the bowl and drank the soup. Then the woman warned him in whispers, "You must go away: you must not stay here." But he said, "I want to smoke." So he took out his knife and cut off the head of the snake, saying as he did so, "Wake up! light a pipe! I want to smoke." Then with his knife he began to kill all the snakes. At last there was one snake who was about to become a mother, and she pleaded so pitifully for her life that she was allowed to go. From her descended all the snakes that are in the world. Now the lodge of the snakes was filled up with dried meat of every kind, fat, etc. Blood-Clot turned all this over to the people, the lodge and everything it contained. Then he said, "I must go away and visit other people."

So he started out. Some old women advised him to keep on the south side of the road, because it was dangerous the other way. But Blood-Clot paid no attention to their warning. As he was going along, a great windstorm struck him and at last carried him into the mouth of a great fish. This was a sucker-fish and the wind was its sucking. When he got into the stomach of the fish, he saw a great many people. Many of them were dead, but some were still alive. He said to the people, "Ah, there must be a heart somewhere here. We will have a dance." So he painted his face white, his eyes and mouth with black circles, and tied a white rock knife on his head, so that the point stuck up. Some rattles made of hoofs were also brought. Then the people started in to dance. For a while Blood-Clot sat making wing-motions with his hands, and singing songs. Then he stood up and danced, jumping up and down until the knife on his head struck the heart. Then he cut the heart down. Next he cut through between the ribs of the fish, and let all the people out.

Again Blood-Clot said he must go on his travels. Before starting, the people warned him, saying that after a while he would see a woman who was always challenging people to wrestle with her, but that he must not speak to her. He gave no heed to what they said, and, after he had gone a little way, he saw a woman who called him to come over. "No," said Blood-Clot. "I am in a hurry." However, at the fourth time the woman asked him to come over, he said, "Yes, but you must wait a little while, for I am tired. I wish to rest. When I have rested, I will come over and wrestle with you." Now, while he was resting, he saw many large knives sticking up from the ground al-

most hidden by straw. Then he knew that the woman killed the people she wrestled with by throwing them down on the knives. When he was rested, he went over. The woman asked him to stand up in place where he had seen the knives; but he said, "No, I am not quite ready. Let us play a little, before we begin." So he began to play with the woman, but quickly caught hold of her, threw her upon the knives, and cut her in two.

Blood-Clot took up his travels again, and after a while came to a camp where there were some old women. The old women told him that a little farther on he would come to a woman with a swing, but on no account must he ride with her. After a time he came to a place where he saw a swing on the bank of a swift stream. There was a woman swinging on it. He watched her a while, and saw that she killed people by swinging them out and dropping them into the water. When he found this out, he came up to the woman. "You have a swing here; let me see you swing," he said. "No," said the woman, "I want to see you swing." Well," said Blood-Clot, "but you must swing first." "Well," said the woman, "Now I shall swing. Watch me. Then I shall see you do it." So the woman swung out over the stream. As she did this, he saw how it worked. Then he said to the woman, "You swing again while I am getting ready;" but as the woman swung out this time, he cut the vine and let her drop into the water.

"Now," said Blood-Clot, "I have rid the world of all the monsters, I will go back to my old father and mother." So he climbed a high ridge, and returned to the lodge of the old couple. One day he said to them, "I shall go back to the place from whence I came. If you find that I have been killed, you must not be sorry, for then I shall go up into the sky and become the Smoking-Star." Then he went on and on, until he was killed by some Crow Indians on the war-path. His body was never found, for the moment he was killed he ascended to the sky, where he now appears as the Smoking-Star.

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This star has not been positively identified. Formerly the Blackfoot practised a ceremonial dance in which a dancer impersonating Blood-Clot wore a stone knife on his head from which the light flashed as he jumped up and down; the Smoking Star was thought to look like this. Some informants placed the star in Orion, probably the Great Nebula in Orion. To the naked eye, this is a hazy (smoky) spot surrounding what appears to be a single star, the middle one of the sword.

Scar-Face

SCAR-FACE was a favorite mythical character among the Blackfoot Indians. They used to refer to him in conversation, and skillful narrators always did their best when rendering the myth. Arthur Nevin wrote an opera based on the adventures of Scar-Face.*

The alternate name for Scar-Face is Mistaken Morning Star. The belief is that often near dawn a bright star will appear which is sometimes mistaken for the true Morning Star. A little later the Morning Star will rise and reveal the mistake. Two planets approaching conjunction would invite such confusion. Anyway the creator of the story used this concept skillfully.

* * *

Once there was a very poor young man who lived with his sister. He had a chum. In the camp was a very fine girl, the daughter of a chief, with whom all the young men were in love. Now the poor young man was in love with her also, but he had a long, ugly scar on

*The title of the opera is "Poïa," the Indian name for Scar-Face. The music was played in 1907 in Pittsburgh, and the Opera was produced in the Berlin Royal Opera House, the first performance having been given on April 23, 1910.

his cheek. One day he asked his sister to go over to the chief's lodge to persuade the girl to marry him. Accordingly, the sister went over; but when the girl found out what she wanted, she said that she was willing to marry Scar-Face whenever that ugly scar disappeared. She made all manner of fun ot Scar-Face.

The sister returned and told Scar-Face what the girl had said. He was very much hurt, and decided to go away to seek some one who could aid him in removing the scar. Yet, though he traveled far, no one could tell him where to go for aid. At last he decided to go to the Sun. So he traveled on and on, and the farther he went, the blacker the people became. As he went along, he inquired for the Sun's house. Always he was told to go on until he came to a very high ridge where some people lived who could tell him the whereabouts of the Sun's house. At last Scar-Face came to this ridge. There he saw a nude man with very black skin and curly hair. Scar-Face called to him. "Where is the Sun's lodge?" "It is at the end of this ridge," said the black man. "But go back! go back! You will be burned very badly!" Scar-Face said, "Well, I shall go on anyway; it is better to die than to go back." "Look at me!" said the black man. "You can see how I have been burned black. You had best take my advice and go no farther." "Where do you live?" asked Scar-Face. "I have a cave to live in," replied the black man. "I stay in this cave when the sun is hot, otherwise I should be burned up." (It was just about sundown that Scar-Face met the black man.) The black man advised him to travel only at night.

Now Scar-Face went on towards the place where the Sun lived. Presently he saw a young man standing alone. The young man called to Scar-Face, "Where are you going?" "I am going to the Sun," said Scar-Face. "Oh!" said the young man. "Sun is my father, this is his house." (This young man was Morning Star.) "My father is a strong willed man. He is not at home now, but when he comes in the morning he will surely kill you. However, I will talk with my mother, who is a tender-hearted woman and will treat you kindly." Then Morning Star took Scar-Face up to his father's lodge, and addressed his mother, saying "Mother, I have brought a strange young man here. I wish him for a companion. He has come a long way to find us, and I wish you would take pity on him, that I may enjoy his company." "Well," said his mother, "bring him in. We will talk to your father when he returns; but I fear we shall not be able to keep the young man."

Now when Scar-Face was taken into the lodge, he saw on the ground a kind of earthen square, with some cedar-brush, and buffalo-chips. This was the altar or sacred place, where Sun burned incense. After a time the old woman who was Moon, said to Scar-Face, "Is there anything that you especially care for?" "Yes," answered Scar-Face, "I want this scar taken from my face." "Well," replied Moon, "it is about time for my husband to come in. If he takes pity on you—well, we shall see." In a little while Moon said, "Now he is coming." Then she took Scar-Face to one side of the lodge and covered him up with cedar. Scar-Face began to feel very warm, because Sun was approaching. He began to shift about under the cedar, but Moon whispered that he must be quiet. So he lay very still, but became very hot as Sun came up. Finally Moon said to Scar-Face, "Now Sun is at the door." Sun looked into the lodge and said, "Oh, my, this lodge smells bad!" "Yes," Moon replied. "Morning Star has a chum here." "Well," said Sun, "make a smudge with cedar (burn it on the altar)."

After this had been done, Sun entered the lodge. Now Scar-Face was very hot. Finally Sun said, "Where is that young man?" "We covered him up," said Moon. "Come," said Sun, "get up." Then Scar-Face came out from under the cedar. He could not look Sun in the face. As Sun looked upon him, he knew that this was a poor unfortunate boy, and took pity on him. The heat then grew gradually less.

Now it seems that Morning Star was out on one of his journeys, and Sun waited for his return. When Morning Star came into the lodge and sat down in his usual place, Sun addressed him, saying, "My son, do you wish this young man for a companion?" Then Morning Star said that he did very much, as he wished for a companion to go about with him. He was lonesome on his journeys through the sky. "Well," said Sun, "you must make a sweathouse." Then Morning Star went out and prepared a sweat-house. When all was ready, Sun went out. He had a disk of metal at the back of his head. This disk looked like brass. Then Sun went into the sweat-house and began to wipe off the metal disk. Then he brought Morning Star and Scar-Face into the sweat-house. When they were in, the covers were closed down. At last, when all was ready the covers were raised and the light let in. The two boys now looked alike.

Now, Moon came out, and Sun said to her, "Which is Morning Star?" Moon looked at them for a moment, then pointed at one; but she made a mistake, for she pointed at Scar-Face. "Oh!" said Sun, "you are a foolish woman! This is the star you mistook for Morning Star. After this, his name shall be Mistaken-for-Morning Star."

Now Scar-Face stayed with his new companion at Sun's house. Sun told him that he could go anywhere in the sky-land except straight west or straight down: he could go in any other direction. One morning, when Morning Star and Scar-Face were out together, Scar-Face said, "Let us go that way," pointing to the west. "No," replied Morning Star. "It is dangerous. My father said we must not go there." "Oh," said Scar-Face, "let us go anyway." Morning Star refused, but at the fourth request he said, "All right, let us go." So the two boys went in the forbidden direction, and presently they came to a place where there were seven large white geese. At once the birds attacked them. Morning Star ran, calling out, "Now you see." Scar-Face did not run, but killed the seven geese with his club, then ran home. Before he reached home, he overtook Morning Star, and said to him, "There is no danger now. I killed all of those birds."

When they reached home, Morning Star told his mother what Scar-Face had done, but she said to Scar-Face, "I will not believe you until you get their heads." So the boys returned and took the heads of the seven birds. (This is supposed to be the origin of scalping, and no one will believe that an enemy is killed until his scalp is produced.)

Some time after this, Scar-Face and Morning Star went out together as before, and Scar-Face said, "Let us go that way again." "No," said Morning Star. "It will be more dangerous than before." Scar-Face insisted, and at the fourth request, Morning Star consented. As they were going along, they saw seven cranes. When the cranes saw the boys, they took after them. Morning Star ran away as fast as he could. These cranes were terrible looking birds, and Scar-Face was badly frightened; but he took off his robe and held it in front of him. As the cranes came up, they began to peck at the robe, whereupon Scar-Face struck them one by one with his club.

Now when Scar-Face reached home, Sun was there and asked where he had been. Scar-Face said that he was walking along when some large cranes took after him, and that he had killed them all with his club. "Oh!" said Sun, "I will not believe it until you have shown me their heads." So Scar-Face returned to the scene of his conflict, and brought away the heads of the cranes. When Sun saw the heads, he believed him. Sun was greatly pleased at the courage of Scar-Face, and brought out a bundle. "Here," said he, "are some clothes for you,—a shirt and leggings. These I give you because you have killed some very dangerous and troublesome birds." Then Sun took up the leggings, and painted seven black stripes on them, saying, "I make these here as a sign that you killed enemies. All your people shall wear black stripes on their leggings when they kill

enemies." Then Sun sang some songs which were to go with the clothes.

After a time, Scar-Face said to Sun, "Now I should like to return to my people. I have been here long enough." "All right," said Sun. "You may go." Then Sun took Scar-Face out, put a hoop or ring of cedar around his head, and, as soon as the hoop was on, Scar-Face found that he could see down to his people. "Now," said Sun, "shut you eyes." Scar-Face shut his eyes. When he opened them, he found himself down by the camp of his people. Now in the camp at that time there were some Indians who were playing at the wheel-and-arrow game; and one of the players, looking up, saw a black object coming down from the sky. He called out, "Oh, look at that black thing!" Then all stopped to look. They saw the object coming closer and closer. At last it reached the ground, some distance from them. It appeared to be a person. Then the old chum of Scar-Face, who was among the young men playing at the wheel-game, recognized Scar-Face, and rushed up to him; but, as he approached, Scar-Face said, "Go back! Go back! Do not touch me. You must get some willows, and make a sweat-house out here from the camp."

Then the chum went back to the people of the camp and explained to them. A sweat-house was prepared. When all was ready, Scar-Face went into the sweat-house with the bundle containing the suit of clothes given him by the Sun. When the bath had been taken, Scar-Face came out, carrying the bundle in his arm. He said to his chum, "My friend Sun gave me a suit of clothes: now I will give them to you."

Now this is why our people say that the sweat-house came from the sun. The medicine-lodge we make at the sun-dance is the lodge of the sun where Scar-Face had been. The weasel-tail suit which Scar-Face brought to his chum was just like those you see to-day. There was a disk on the back and one on the front. There were seven black stripes on the sleeves. These were for one group of seven birds that Scar-Face had killed. Sometimes the feet of these birds are painted on the shirt. The seven bands on the leggings are for the seven other birds that Scar-Face killed. Scar-Face directed that only such persons as performed great deeds were to be allowed to wear such a suit.

After a time Scar-Face longed to see his friend Morning Star and so returned to the sky where he has been ever since. He is sometimes called the chum of Morning Star, or the Mistaken Morning Star, but usually just Scar-Face.

The Twin Brothers

A LONG time ago there was a man by the name of Smart-Crow. When he traveled, he always went by himself. One day after he was married he told his wife that in the future two children would be born to them, both boys. He predicted that one of them would be disobedient and the other reliable. Smart-Crow knew this, because a crow had given him the information in a dream. This crow also told him, that, before his two children were born, an evil man would try to kill their mother. The crow told the man that he must warn his wife. It said, "This man will come to the lodge when you are away, and ask to come inside. Your wife must say nothing to him. He will repeat the visit four times." The next time Smart-Crow went out to hunt, he told his wife about this dream, and warned her not to speak to the strange man.

While Smart-Crow was away, the strange man came and stood before the lodge. After a while the woman thought to herself, "Why does not this man come in?" Now, the stranger had great power. He read the woman's thoughts, and, as soon as she thought this, the man answered by saying, "I will tell you why." So he entered the lodge and sat down, saying as he did so, "I knew you wished me to come in." Now the woman began to cook some meat for the stranger, and when it was ready, she put it in some wooden bowls, and placed it before him. There were four kinds of bowls in

the house. Some were made of hard knots of wood; some of bark; some of buffalo-horn; and some of mountain-sheep horn. After the woman had cooked the meat, she placed it before the stranger in a wooden bowl. The stranger looked at it and said, "That is not the kind of bowl from which I take my food." Then the woman took the food, and, putting it into a bark bowl, offered it to him again. "No," he said, "I do not take my food from bark." So the woman took the food, placed it in a bowl of buffalo-horn, and offered it to him for the third time. Again he refused, saying that he did not take food from horns. The woman took back the food, and, putting it in a bowl of sheep-horn placed it before him; but he refused to take food in such a dish. Now the woman was troubled, and looked about the lodge for something in which to serve the food. Finally she saw a piece from the horn of a moose, and offered him food upon it. This he refused also. As she looked about for something else, she happened to see a blanket. "That will not do, either," said the stranger. Then she offered her dress. "That is near the kind I must have," he said. Then the woman said, "Oh, well, I will put the meat on my breast." "All right," said the stranger. The woman then lay down on her back, and placed the meat on her breast. The stranger had a white stone knife, which he sharpened and began to cut the meat. Three times he cut the meat; but the fourth time he said, "I came near cutting you." The fifth time he cut the woman open, killing her. Then the stranger saw two infants in the lodge. They were twin brothers.

The stranger took one of them, put him down near the ashes, and as he did so said, "You shall be called Ashes-Chief." Then he took the other, stuck him behind the lining of the lodge, and said, "You shall be called Stuck-Behind." Then the man went away. He carried a small lodge, with the skin of a running-fisher for a pennant.

After a while Smart-Crow returned from his hunt, bringing much buffalo-meat. As he came over the hill near his lodge, he saw no smoke rising from the smoke-hole. "Now," he said to himself, "I know what has happened. I knew that woman would invite the stranger in." When he entered the lodge, he saw Ashes-Chief lying by the fire. While he was looking at his wife's body he heard the other infant crying behind the lodge-lining.

Now Smart-Crow was very angry, and rushed out in pursuit of the stranger. He followed his trail and soon overtook him. As he came up, he said to the stranger, "Now I shall kill you." "My friend," said the stranger, "I will restore her to you." "I do not believe you," said Smart-Crow. "My friend, I tell you I will restore her," repeated the stranger. "I cannot believe it," said Smart-Crow. "My friend," said the stranger, "I will restore her to you." "You are a liar," said Smart-Crow. Then the stranger began to sing a song. The words of this song were as follows:—

> "I am a great medicine (powerful.)
> Everything in the ground hears me.
> Everything in the sky hears me."

When Smart-Crow heard this song, he believed in the promise of the stranger. Then the stranger took the bundle from his back, and said, "I give you this lodge and the running-fisher skin." The stranger set up the lodge. There were four buffalo-tails hanging to its sides. Two of these were cow-tails, and two were bull-tails. One of each hung in front, and also behind. This lodge was called the Four-Tail Lodge. The stranger told Smart-Crow that the hanging of the buffalo-tails on the lodge would make the buffalo range near it, so that the people would always have meat. The stranger transferred this lodge to Smart-Crow. He sat down upon a stump, explained the ritual to him, and also taught him the songs. Among other things he said, "The punk which you use to make fires is made of bark, and does not kindle quickly; take puff-balls (fungus) instead, for they are much better. They are the Dusty Stars. You are to paint these stars around the bottom of the lodge. At the top

of the lodge you are to paint the Seven Stars on one side and the Bunch Stars on the other. At the back of the lodge, near the top, you must make a cross to represent the Morning Star. Then around the bottom, above the Dusty Stars, you shall mark the mountains. Above the door, make four red stripes passing around the lodge. These are to represent the trails of the buffalo."

When Smart-Crow had received all of the instructions belonging to the new lodge, and had learned all the songs, he went away with it and returned to his own lodge. He picked up Ashes-Chief, and said to a large rock lying near by, "I give you this child to raise." Then he pulled down the lining of the lodge, picked up Stuck-Behind, and called out to his friend the beaver, "I give you this child to raise." So the rock and the beaver took the boys away.

The boys grew up. When they were about six years old, Smart-Crow began to wish that he might have them with him again. He went out to get them back; but the boys were wild, and knew nothing about people. So, when the boys saw him coming, Ashes-Chief ran into the rock and Stuck-Behind into the beaver's house. Then Smart-Crow took some arrows from his quiver, laid them down near the rock, and concealed himself in the bushes. After a while, Ashes-Chief came out, saw the arrows, and looked curiously at them. As the boy was about to pick them up, Smart-Crow sprang out and caught him. Now Ashes-Chief had been raised by the rock, and was so strong for his age that Smart-Crow was scarcely able to hold him. He saw that his son would soon break away; so he said, "Ashes-Chief, lick my hand, and you will know that I am your father." Then Ashes-Chief licked his hand, stopped struggling, and said, "Yes, you are my father, and I will go with you."

Now Smart-Crow was anxious to secure Stuck-Behind, and advised with Ashes-Chief as to how to proceed. Finally they decided to draw him out of the beaver's house by playing the hoop-game. Smart-Crow concealed himself near the house while Ashes-Chief began to roll the hoop back and forth near the door. Stuck-Behind became curious to know about the hoop, and ventured out to play. When he was outside, Smart-Crow sprang upon him, and held him fast. Now, Stuck-Behind had been raised by the beaver, and for that reason was very hard to hold. Smart-Crow said to him, "Lick my hand, and you will know that I am your father." He did so, and recognized his father.

When the boys were at home with their father, their names were changed. Ashes-Chief was now called Rock, and Stuck-Behind was called Beaver. Thus were they separated from the rock and the beaver. Rock was the adventurous one, and Beaver the good one, as the crow had told their father in the dream. One day Rock said to his father, "Make me a bow and two arrows." "What do you want with bows and arrows?" said Smart-Crow. "Well," said Rock, "Beaver and I wish to go out to hunt buffalo. While we are gone, you must go back to our old lodge where the bones of our mother lie, and cut a stick such as she used for stirring the meat when cooking. Wait there for us until we bring the meat." Then Rock and Beaver went on their way to hunt.

Now, at this time, the people cooked in pots of clay. These were shaped out of mud by the hands, and put in the sun to dry; then the kettle was rubbed all over with fat inside and out, and placed in the fire. When it was red hot, it was taken out, and allowed to cool. Such a pot was good for boiling. Rock told his father to take one of his mother's pots, fill it with water, and put it over the fire so that it might be ready for his mother to boil meat.

After a while the boys came up to their mother's lodge, where her skeleton lay. They had a great deal of meat with them. Rock said, "Now, I shall take a little meat from each part of the buffalo, boil it in the pot, and then make medicine to put over the skeleton of our mother." Beaver said, "I shall help mother with

the heart, the brains, and the marrow." Rock took up the tongue, blew his breath on it four times, and put it into the pot. Then he took up the other parts, one at a time, and did the same. The brains and marrow, however, he laid to one side, and did not put them into the pot. Rock said to Beaver, "I will help mother in two things and you may help her in the other two things." Now Smart-Crow was lying down in bed. The boys took his robe, and covered their mother's bones. Then the pot began to boil more than ever, and Rock said to his father, "Get up, call mother, and tell her that her pot is about to boil over."

The father arose from his bed, went over to the place where the robe lay, and said, "Get up, woman! Your pot is about to boil over." The bones did not move. Then Beaver called, "Mother, get up quick! Your pot is boiling over." At this there was a little movement under the robe. Then Rock called out, "Mother, get up quick, and feed us!" At this there was much movement under the robe, and parts of the woman's feet could be seen beneath the edge. Now Beaver called to her, which made the fourth time, saying, "Mother, get up quick! I have a heart, brains, and marrow for you to eat."

The woman sat up and drew a deep breath. "I have had a long sleep," she said. "I am very hungry: I shall eat." The boys gave her some of each part of the buffalo to restore her to life. For eyes, they gave her the inside of the eyes; for brains, they gave her the brains; for tongue, part of the tongue; for heart, part of the heart, and so on. When she had eaten all of these, she got up and set food before her children and Smart-Crow, as she had always done.

Then Smart-Crow said to his wife, "Let us move from this place, it is an unlucky place for us. Let us leave this lodge here and take the new one given me by the stranger. When this new lodge is up in a new place, make a sweat-house, that I may go through it, for we have a medicine-lodge now. I did not kill the stranger, because he promised to restore you to me, and gave me this new lodge. After all I have seen, I believe that this lodge is very powerful. You have been asleep for a long time. Your bones were bleached, now you are alive; and it is the power of this lodge that made you so. When we are old, we will give this lodge to Beaver; he is a good man. Rock, on the other hand, is no good, and he will not live long.

When the mother had put up the new lodge in a new place, she made a sweat-house. Smart-Crow put the skin of the running-fisher around his shoulders, painted his face, took off his breech-cloth and moccasins, and was ready to go through the sweat-house. Then he covered the sweathouse with the skin of the new lodge, that it also might be purified. When he came out of the sweat-house, he painted his wife and children, and, taking up the lodge, put it in place. When all this was arranged, the woman looked at the lodge, admiring it. "What are those round things at the bottom?" she said.

"Those," said Smart-Crow, "are for two purposes. They will help us to live long and to make fire quickly." When they had gone inside of the lodge, Smart-Crow said to his wife, "Now I shall teach you how to use the smudge." Then he took some moss from the pine-tree and laid it upon the fire, singing a song. "You are to do this," he said, "every morning and every night. Also you must sing two-seven songs (fourteen) that I shall teach you."

Now all this time Smart-Crow had been away from his people; but now he returned with his family and the new lodge. This created a great sensation.

The hoop that was used in catching Beaver was the big game-hoop. Rock and Beaver often played at this game. One day their father told them that they must not roll the hoop in the same direction as the wind. Then they went out to play. Now Rock said to Beaver, "There is no reason why we should not roll this hoop

with the wind. Nothing will happen if we do." "Oh," said Beaver, "our father requested us not to do this, and we should obey him." However, Rock paid no attention to what he said, and started the hoop in the direction of the wind. Now, the hoop continued to roll and roll. It would not stop, and as the boys followed along, waiting for it to fall, they were brought near a rock lodge. As the hoop rolled by, an old woman came out, took it in her hands, and invited the boys inside. They both went in.

This old woman had some kind of power. She killed people by suffocating them with smoke. As soon as the boys were seated, she took out a large pipe with a man's head for a bowl. Then she placed a great heap of wood on the fire, and, after shutting the door and the ears (smoke-hole) of the lodge, lighted the pipe and made a great smoke. Then the old woman said to the boys, "Smoke with me." "No," said Rock. "You must," said the old woman, "because it is the custom for the guest to smoke with the head of the lodge."

Now this old woman was a cannibal, and the boys knew it. So Rock said to the old woman, "Well, I will smoke with you." But Beaver refused. Then the old woman gave back the hoop, which Beaver took and put over his head. Rock took out a yellow plume and tied it to his hair. Both of these things had power. The hoop kept the smoke away from Beaver's head, so that his head was in a hollow place surrounded by thick smoke. The plume in Rock's hair whirled in the air, and kept the smoke from his face. Now the smoke was so thick at last that the old woman could not see. She did not know that the boys had such great power. It became so thick at last that she was almost suffocated herself. "Oh!" she said, "there is too much smoke." She tried to rise to open the door, but fell down dead. Then the boys went outside of the lodge, and called out as if talking to the old woman. In this way they made all manner of fun of her great power. Looking around, they found themselves near the rock that had raised Rock. Then Rock took an arrow from his quiver, spit upon the point, dipped it into the water, and, pointing toward the rock, asked it for help, saying, "Make the arrow do what I wish." Then he threw the arrow at the lodge in which the old woman lived. It struck at the bottom, making a hole from which the water began to flow. The stream continued to increase in size until it carried the lodge and rock away. Then the boys went home. Rock told his father everything that had happened, and laughed a great deal.

There was a tall tree upon which grew some fine berries. Their father said to them, "You must not eat those berries." Some time after, when the boys were out by themselves, Rock looked up at the tree, and said to Beaver, "Come, let us get some of those berries." But Beaver said, "No. Every time father requests us to do a thing, you do the opposite." But as Rock insisted upon getting the berries, Beaver consented. Now, beneath this tree lived a snake with a large horn in the middle of his head. When they came near the tree, Beaver was afraid, and said to Rock, "I do not wish to climb the tree. You get the berries." Then Rock began to climb the tree, and, when he was up in the branches, the snake came out of the bushes and began to climb the tree. When the snake came within reach, he tried to hook Rock; but, missing, his horn struck the tree and stuck fast. Then Rock broke the tree and twisted the trunk, which pulled out the snake's brains. This snake always killed people who came to gather berries. Then the boys took some of the berries and went home. Rock related the adventure to his father, and laughed as if were but an incident.

Once they were forbidden to shoot at the morning-bird. Now the morning-bird was a very powerful creature; every one was afraid to do anything to him. One day when the boys were out, they saw this bird, but could not get at him as he was high in the air. Later they saw the bird near the ground, and Rock sug-

gested to Beaver that they send an arrow after it. Again Beaver tried to persuade Rock to heed the commands of their father; but without success. So Rock shot an arrow into the bird. It fell into the branches of a tree, almost within their reach. Rock stood upon a log and tried to reach the bird; but every time he tried, the bird got a little higher. Then he got upon a limb, and finally into the tree itself. Then, as he climbed the tree, the bird went higher and higher, and the tree became taller and taller, until Beaver, who stood upon the ground, could not see them. Now Beaver felt very much ashamed that he had yielded to his brother's folly. He did not feel like going home to tell his father, so he sat down by the tree and began to cry. When this happened, the boys were men, but Beaver cried so much at the foot of the tree that he became a dirty little ragged boy.

At this time the Blackfoot were out looking for buffalo, but could find none. They were forced to live upon such berries as they could find. One day an old woman gathering berries heard a child crying. Looking around, she found Beaver at the foot of the tree. He was almost starved. The old woman felt sorry for him, picked him up and took him home. She gave him to her daughter to care for, saying, "Here is my grandson. When he grows up, he will run errands for us. You must feed him." Now, as they had no meat from which to make soup for the child, the daughter gathered some old bones around the camp and boiled them in a kettle. A few days after this the chief of the camp, who had two beautiful daughters for whom there were many suitors, made a public announcement. He said, "To-morrow morning a prairie chicken will sit upon a tall tree near the camp, and all the young men are to shoot at it with bows and arrows. The man who hits it first shall receive my eldest daughter for a wife.

Now Beaver was a very dirty little fellow; every one in the camp talked about his uncleanliness. When he heard what the chief said, he said to the old woman who found him, "Make me some arrows and I will try to hit the bird." "Oh, you dirty thing!" said the woman in disgust. "You are a disgrace to the camp; you would nauseate everybody. The girl would not have you anyway." The boy insisted that the arrows should be made for him; and, the fourth time he made the request, she made him a bow and four arrows. All were very poorly constructed.

When the time came for the young men to try their skill at shooting, the little boy came among the crowd, wearing an old piece of skin for a robe. He was pot-bellied. His eyes were sore and dirty. The people made fun of him. "What can you do?" they said. "What brought you anyway?" So they threw dirt at him and mocked him. Then the shooting began. One after the other, the young men discharged their arrows at the bird; but no one made a hit. Beaver looked at the bird in the tree, then discharged one of his arrows, which came near hitting the bird.

Now there was a man in the crowd called Crow-Arrow, who had never been able to get a wife. He observed that the boy had some kind of power, and envied his success. He got his bow ready to discharge an arrow at the same time as the boy, and, in case the bird was hit, he would dispute the ownership of the arrow. When the boy discharged his second arrow, Crow-Arrow discharged his also. The boy's arrow struck the bird, and it fell to the ground. Crow-Arrow, who was very swift, ran at once to the spot, pulled out the boy's arrow and put in his own. The people, who were all looking on, said, "No, it was the boy who hit the bird." Then they all went before the chief, and announced to him that the little dirty boy had won; but Crow-Arrow insisted that it was his arrow that killed the bird. The chief looked at the small dirty boy with disgust, and said to himself, "I cannot have him for my son-in-law, even if he did hit the bird." Then he said to the people, "Since there is a dispute about this, we will try something else. All the

young men shall set wolf-traps, and whoever gets a black one or a white one shall be my son-in-law.

Beaver went home and asked his grandmother to make him a wolf-trap. The grandmother said, "Oh, you get away from here,' you dirty boy! No wolf would ever go into a trap you touched." But as Beaver insisted, she fixed up a trap just back of the lodge. In the evening, Beaver went out to fix his trap, and when morning came there was both a black and a white wolf in his trap. Now Crow-Arrow had set a trap also, and in the morning found a black wolf in his trap. Crow-Arrow hurried to the chief with his prize; but when he got there he found Beaver with two wolves, one black and one white. "Well," said the chief, "there is no dispute about it this time. The little dirty boy must be my son-in-law.

So the eldest daughter was dressed up, her face painted, and taken over to the lodge where Beaver lived.

Now Beaver always defecated and urinated in his bed. When the girl saw him she was disgusted, for his eyes were dirty and his abdomen was very large; but she gave him some food. As he ate, the girl noticed how filthy and repulsive he really was and became nauseated. She said she would not live with such a husband as this, and went over to live with Crow-Arrow. When the chief heard this, he was angry, because he knew that the little dirty boy possessed some kind of power, for which reason his daughter should have kept her promise. So, to make amends, he sent his youngest daughter over to be the wife of Beaver. Now this girl was rather bashful, and when she came to the lodge where Beaver lived, she got behind the old woman, and, peeping out at him, whispered, "I think that boy is very pretty. I shall stay with him because he is so nice, and I see no reason why my sister left him."

Now all this time the people had been without meat, and the chief sent out the young men in every direction to look for buffalo, but none were seen. Beaver said to his wife, "You are to go home to-night and stay with your mother until I send for you." He said to his grandmother, "You also must go away from this lodge and not return until I call you. You must leave me alone here." As soon as they were gone, Beaver took some yellow paint, put it in the hollow of his hand, mixed it with water, and painted his entire body. Then he took hold of his hair, pulled it down and painted it. At once he became a man, as before. Before him stood the Four-Tail Lodge of his father. In it was a dress covered with elk-teeth for his wife, also a fine white robe for himself. There were beds and other furniture in the lodge. Then Beaver sent out for the old woman, his grandmother, and when she came up directed her to wait outside of the door. Then he brought out a fine dress covered with elk-teeth, and told her to put it on. As soon as she did this, she became a young woman again. Then he sent the grandmother over to the lodge of the chief to call his wife. The young woman did not recognize the grandmother, but followed her as requested; and when she came to the strange lodge she also failed to recognize Beaver. Beaver explained to her what had happened, and told her that she was to be rewarded for her kindness to him when he was such a dirty little boy. He brought out to her a fine dress covered with elk-teeth, and, rubbing paint upon her hair, pulled it gently until it became very long. Then he sent his wife to her father. When she came in she said, "Father, my husband is about to go out to drive the buffalo over into the enclosure. There will be one white buffalo in the herd, and my husband requests that no one shoot it, but that it be roped and then knocked on the head so that no injury be done to the skin, for it is to be made into a robe."

All the young men of the camp went out with Beaver to drive the buffalo. Crow-Arrow also went. Beaver took a white rock and placed it near the edge of the enclosure, then he took up a rock colored like the beaver, and placed it on the other side. Then he directed the young men to lay rows of rock spreading out-

ward from these two. Then they laid down between them some buffalo-chips. As they were putting down the last, Beaver shouted four times. Everybody looked around. They saw a herd of buffalo, a white one and a beaver-colored one in the lead. Then the men hid behind the rocks. This was a buffalo-drive.

When the people were going out with Beaver to prepare the buffalo-drive, Crow-Arrow came upon an old buffalo-carcass. He cut out some of the spoiled meat, and carried it back to the chief to make him believe that he had the power to get meat first. While Crow-Arrow was on his way back, he heard the shouting and the noise of the buffalo going over. He ran up as quickly at he could, and saw the white buffalo already roped and about to be knocked upon the head. Looking around, he saw the beaver-colored one and shot it. When the buffalo were killed, Beaver called to his wife, directed her to take his arrows, rub them over the skin of the white buffalo, and throw them away. These arrows were feathered with eagle-tails. As the woman threw them from her, all the young men fought for them, because they were regarded as very good medicine. When Crow-Arrow saw this, he directed his wife to take his arrows and do likewise with the skin of the beaver-colored buffalo. Crow-Arrow's arrows were made of crow-feathers. Now when Beaver's wife rubbed the arrows over the skin of the white buffalo, it was made smooth and clean; but when the wife of Crow-Arrow rubbed the skin of the beaver-colored buffalo, it did not change. So when she threw her arrows away, no one seemed anxious to pick them up. Now the wife of Crow-Arrow, the same one who deserted Beaver, felt ashamed. She came close to Beaver, and said, "I wish you would give me some of your arrows to clean the skin." "No," said Beaver. "Once I married you, but you refused to live with me or to clean me: now I shall not help you clean skins." When Crow-Arrow saw what had happened he was angry, and went home with his wife. He was angry because Beaver seemed to have greater power than he. Now Crow-Arrow was a great medicine-man, and so he transformed himself and his family into crows, and they flew out at the top of their lodge. Then these crows flew around over their lodges and mocked the people in crow-language, "We shall starve you; we shall take all the buffalo away from you, and starve you to death."

After this no buffalo were seen in the country, because the crows took the buffalo over the mountains. Beaver and his people were soon driven to starvation; but the crows returned, flew around over their lodges and mocked them. So Beaver called the people together in council and said to the young men, "What can you do? Has any one power to bring back the buffalo?" No one seemed to have such power. This was in the winter. Then Beaver said, "Let two young men go to the place where the beaver lives, cut a hole in the ice, build a fire and try to smoke the beaver out. Then I shall transform myself into a beaver and lie by the hole as if dead." The young men did as directed. During the night, Beaver went down to the place, transformed himself into a beaver and lay down upon the ice as if dead. Part of the skin was pulled away, and his entrails could be seen. While he was lying there, Crow flew up, looked down, and said, "Oh, yes! I know your game. I know you. It is no use for you to try to get me in this way. Your people will starve. You think you are very smart, but you cannot get me. It is no use to try me in that way, because I know too much." None of this made any impression upon Beaver, who looked precisely like a corpse. Then Crow said to himself, "Well, after all, I believe it is a real dead beaver." He came down and looked closely at the corpse, and pecked at the breast and eyes. They were all frozen hard: he could not make a dent in them. So Crow took up a piece of fat from the entrails. He flew to a place and began to eat. Then he said, "Yes, it is a real beaver." Then Crow went back to the corpse and began to eat. Beaver lay still for a while, but suddenly transformed himself into a man, sprang upon Cdow and caught him. As he struggled, Crow cried, "Let me go! let me

go! I will get buffalo for you." "No," said Beaver, "you are a liar. I shall hold on to you this time. I shall surely punish you." So he broke the wing of Crow, took him home and tied him to the smoke-hole of the lodge. Then Beaver gathered a lot of birch-wood and threw it into the fire, making a very black smoke. Now, up to this time, all crows were white; and while Crow was crying in the top of the lodge, "Oh, let me go! let me go! I will bring you buffalo surely," the smoke made him black, and crows have been black ever since. After Crow was as black as he could be, Beaver consented to let him go if he would call the buffalo. Crow promised, but, as soon as he was released, he flew to the top of a lodge and called back, "I shall let you starve, I shall let you starve. I was just fooling."

Then the people of the camp scolded Beaver. They said, "You knew that he was a liar. You knew that he would not keep his word. You should have kept him fast until he produced the buffalo." "Well," said Beaver, "I will get the buffalo myself." One of the men said, "I should like to go with you." "What kind of power, have you?" said Beaver. "Well, I have some power," said the man. "I can transform myself into a swallow, a pup, and a spider." "Well, you have some power," said Beaver, "but I have greater power. I can transform myself into anything, but you may come with me."

The name of this man was Little-Dog. He transformed himself into a swallow, and Beaver became a prairie-chicken. Then they started out to look for buffalo. As they went along, Little-Dog saw Crow's camp in the distance. Then he transformed himself into a spider, and, coming up to a man belonging to Crow's camp, inquired of him the whereabouts of Crow. The man informed him that he had gone over the mountain to live, and that there was a very high cliff behind them. Then Little-Dog transformed himself into a swallow, and Beaver into a horse-fly. Together they flew over the cliff. Here they saw Crow's camp. While they were looking, Crow's people moved their camp. Then Little-Dog transformed himself into a spider, and Beaver became a pine-tree. Now the two watched a long time for the buffalo; but they saw no trace of them around Crow's camp. One day they saw Crow go away. Then they went to the place where the camp was first seen, and Beaver transformed himself into a digging-stick, and Little-Dog became a pup. After a while the young daughter of Crow came out to look around the old camping-place. She found the digging-stick and the pup, and carried them home with her. When she came up to the lodge, her mother was tanning a hide. The girl said to her, "Mother, these things were left behind when we moved camp." So the woman thought no more of it, and the girl took the two into the lodge to play. Now the girl was very fond of the pup, and carried it about in her arms, with the digging-stick stuck on her back in the way that women carry babies. While the girl was playing with the pup, as children do, she raised up the edge of the bed. There was a deep hole under it, and, holding the pup over it, she said, "Pup, do you see that deep hole? Do you see all the buffalo down there?" Now Little-Dog and Beaver looked down into the hole and saw where the buffalo were hidden. As the girl was looking over, the digging-stick slipped from her back into the hole, and pup grew into a large dog, so large that he slipped down of his own weight. The girl was very much frightened, but went away without saying anything to her mother.

So Beaver and Little-Dog fell down into the hole. Beaver transformed himself into a man, and Little-Dog became a monstrous dog. At once he began to bark and chase the buffalo, and ran after them shouting. This frightened the buffalo so much that they dashed up through the hole and out upon the earth. There were so many buffalo that it took them a long time to get out; so that Crow returned while Beaver and Little-Dog were still driving buffalo. Crow knew who was driving them out, and took his station by the side of the hole, waiting to kill them. However, they were not to be caught so easily. Beaver caught hold of a buffalo, transformed himself into a stick, and

concealed himself in the long hair of the neck. Little-Dog became a pup once more, and fastened his teeth in the long hair of the breast of a buffalo. Thus they were carried out, unobserved by Crow.

Now the buffalo were running over the earth, they were restored to the people once more.

After this, Beaver returned to his people. One day he told his wife that she must never put sagebrush on the fire as it was against his medicine; but one day his wife forgot this, and threw the sagebrush into the fire while Beaver was away. When Beaver came in, he knew what had been done. He said to his wife, "Now, since you have used the sagebrush for the fire, I must leave you and go to my brother. You will never see me here again." Then he took his white robe and a plume. He blew the plume up into the air and rose to the sky. His brother had been carried to the sky on the branches of a tree, and Beaver went up to him. Now they are both stars. Every night we see two large stars side by side: these are the two brothers, Ashes-Chief and Stuck-Behind. They became the Twin Stars (Castor and Pollux).

METEOR CRATER, ARIZONA

by

CLYDE FISHER

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GUIDE LEAFLET SERIES, No. 92

The American Museum of Natural History
New York, New York

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By CLYDE FISHER

CURATOR OF ASTRONOMY AND THE HAYDEN PLANETARIUM,
AMERICAN MUSEUM OF NATURAL HISTORY

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The Meteor Shower of 1833.

An old wood-cut from Grondell's "*Music of the Spheres*" illustrating the Leonid shower of November 13, 1833, the greatest phenomenon of the kind on record. Compared to a fall of snowflakes. (See cut at top of page 13.)

Meteor Crater, Arizona

Where a huge, dense mass of iron meteorites struck the earth, probably 50,000 years ago, the impact of which crushed and dislodged some 300,000,000 tons of rock

By Clyde Fisher,

Curator of Astronomy and of the Hayden Planetarium, American Museum of Natural History

A METEOR shower is one of the most impressive phenomena in the whole realm of nature. Its sudden appearance, together with the suggestion of falling or shooting stars, excites wonder and fear, especially in untutored and primitive minds. Various tribes of American Indians used the November shower of 1833, the greatest meteor shower on record,—"the rain of stars,"—as a milestone in their calendars.

While showers or swarms of meteors are comparatively infrequent, the adventitious or occasional meteors are extremely common. It is estimated that about 20,000,000 meteors enter the earth's atmosphere every twenty-four hours. Most of these are exceedingly small, weighing perhaps only a few grains each. When we recall that there are 7,000 grains in a pound, Avoirdupois, we realize how tiny these meteors must be. Practically all of the meteors that penetrate the earth's atmosphere, day after day, are burned up due to the heat generated by friction with the air, and consequently do not reach the earth.

Few fall to the earth

Occasionally, of course, one comes clear through to the earth, and, if found, it is called arbitrarily a "meteorite", the name "meteor" usually being reserved for those which enter the earth's atmosphere, but which do not come through to the earth. Nearly 1,000 falls of meteorites are known, of which more than 550 are represented in the collections of the American Museum of Natural History.

Half the falls observed

Although nearly 500 falls of meteorites have actually been observed, the phenomenon still attracts much attention, and well it might, for these are the only direct messengers from space that come to the earth, the only heavenly bodies besides the earth that we can actually touch. A recent fall to be observed was that of July 1, 1933, when two masses of stony meteorite were seen to fall near Spartanburg, South Carolina, one weighing about twelve pounds and the other about half as much. This fall occurred in the daytime, and was observed by several persons.

During the last few years it seems that more than the usual number of large meteors, sometimes called fire-balls or bolides, have been observed. On March 24, 1933, a gigantic meteor flashed across five southwestern states. An airmail pilot flying near Amarillo, Texas, declared that it looked as big as the hangar at the Wichita Airport. Some most unusual and striking photographs of the train left by this fire-ball were secured at Timpas, Colorado, by Mr. C. R. West. In northeastern New Mexico Mr. Charles M. Brown succeeded in photographing the meteor, which showed a cork-screw train at the moment,—securing an absolutely unique photograph. Professor H. H. Nininger succeeded in locating a number of pieces of this fall in northeastern New Mexico, along a line twenty-nine miles long, for which success he deserves much credit. It proved to be a stone meteorite or rather a group of meteorites, one specimen of which, picked up near Pasamonte, New Mexico, was shown to me by Professor Nininger. On September 27, 1934, another huge meteor was observed in California by an airplane pilot who thought it necessary to swerve his plane to keep from colliding with it.

In this case no meteoric material constituting a fall has been located. On March 14, 1936, a brilliant fire-ball swept over a half-dozen north-eastern states, and although a number of supposed fragments of this meteor have been picked up, none has yet proved to be a real meteorite.

Most great falls prehistoric

The greatest falls of meteoric material known on the face of the earth were not observed. In fact, with the exception of the Siberian fall of June 30, 1908, all of these occurred without much doubt in prehistoric times. The first crater, the cause of which was determined to be due to the impact of a meteorite or mass of meteorites, was Meteor Crater in Arizona. It was not until the early years of this century that the theory that this crater was caused by the impact of meteoric or cometary material was set forth by Mr. Daniel Moreau Barringer, geologist and mining engineer of Philadelphia, and to him must be given the credit for convincing scientists of the truth of his theory.

Meteor Crater is best seen from the air, and consequently the most satisfactory photographs have been made from an airplane. A huge circular crater, nearly a mile in diameter and nearly six hundred feet deep, with a conspicuous elevated rim, formed in solid limestone and sandstone, constitutes an impressive challenge to one's innate desire to understand the causes of things. Svante Arrhenius, the great Swedish scientist, author of the electrolytic theory of matter, is said to have declared that Meteor Crater is the most interesting spot on Earth.

Located in Coconino County, in north-central Arizona, about twenty miles west of Winslow and thirty-five miles east of Flagstaff, the crater is easily reached by the Santa Fé Railroad or by U. S. Highway 66.

First seen by white men some sixty years ago, although doubtless known to the Indians long before, it was formerly known as Coon Butte or Coon Mountain, the latter part of the name referring to the elevated rim.

Dr. Charles R. Toothaker, Curator of the Philadelphia Commercial Museum, who had much to do with the Meteor Crater iron in the early days, writes me as follows:

"It appears that in 1886 some shepherds were in the neighborhood of Cañon Diablo, Arizona, and one of them named Mathias Armijo found a piece of this iron and thought it was silver. Some time later, a man staked a claim and put the samples in the hands of a chemical firm named M. B. Booth & Co., in Albuquerque, New Mexico, in March 1891.

"Dr. A. E. Foote of Philadelphia was at that time a dealer in mineral specimens and I was employed by him. I remember when the first news of this matter reached Dr. Foote. He went to Cañon Diablo at once and sent back a piece of the iron which was immediately put in the hands of Professor G. A. Koenig, Professor of Chemistry in the University of Pennsylvania. Koenig analyzed it and discovered diamonds in this iron."

Crater at first misunderstood

This crater was at first explained by the scientists of the U. S. Geological Survey as the result of a steam explosion. Because of the absence of lava and other evidence of volcanism, no scientists have believed it to be a volcanic crater. One writer advanced the theory that it was a limestone-sink. But the credit for the conception and establishment of the theory that is now well-nigh universally accepted goes to Mr. Barringer,—and a magnificent conception it was. He set forth the idea that this crater was the result of the impact of a huge, dense mass of iron meteorites, possibly the head of a small comet, and this theory has now come to be held by nearly all geologists, physicists and astronomers.

This meteoric mass penetrated 40 to 50 feet of purplish-red sandstone (Moencopie Formation —Triassic), which lies next below the thin soil of the surrounding plain; then crashed through some 300 feet of Kaibab Limestone (Permian Age), the same rock that outcrops in the Grand Canyon of the Colorado in north-western Arizona, and that caps the eroded pinnacles in Bryce Canyon in Utah; then it plowed into the Coconino Sandstone (Permian Age), which underlies the Kaibab Limestone, shattering this stratum to a depth of some 600 feet, or practically to the Supai Sandstone or "Red Beds" (Permian) underneath.

The meteoric origin of the Crater is suggested by the occurrence of literally thousands of pieces of meteoric iron around the crater.

These fragments were found as far as four or five miles from the crater on all sides, but the nearer the Crater, the more numerous they were. In other words, Meteor Crater is about in the exact center of an area from which have been collected many more specimens of meteoric iron than have ever been found on all of the rest of the earth's surface.

The larger specimens

The largest piece of which I have knowledge is in the Colorado Museum of Natural History in Denver, and it weighs 1,406 pounds. For this information I am indebted to Professor H. H. Nininger, Curator of Meteorites in that Museum. The second-largest piece is in the American Museum of Natural History and weighs 1055 pounds (re-weighed in 1935 upon removal into the Hayden Planetarium). The third-largest piece, now in the Field Museum of Natural History, weighs 1,013 pounds, according to the late Professor O. C. Farrington, Curator of Geology in that Museum. The fourth-largest piece of which I have knowledge is in the Smithsonian Institution collection in charge of Mr. E. P. Henderson, Assistant Curator of Physical Geology. It is labeled and recorded as weighing 1,000 pounds. Mr. Henderson informs me that they also have in their collection another piece weighing 960 pounds and still another weighing 746 pounds, besides a great many others of lesser weight. Another large piece is located near the front door of the Fred Harvey Indian Building in Albuquerque, New Mexico, which, according to Mr. H. Schweizer, weighs 625 pounds. It is estimated that between ten and fifteen tons of meteoric iron have been shipped away from Meteor Crater, all of which has been collected within about five miles of the crater, most of it in the immediate vicinity.

Meteorites have been known to burst in the air just before striking the earth, but very few, if any, of the individual pieces of Meteor Crater iron, whether large or small, show evidence of the bursting in air of an enormous meteorite. For this reason it is believed that the crater was formed by a huge meteorite accompanied by thousands of small ones, or more probably by a huge, dense mass of comparatively small, iron meteorites.

Composition

The meteoric iron from the vicinity of Meteor Crater, known as Canyon Diablo iron, named from a gorge located about three miles to the westward, is remarkable in its composition, for it contains 91 to 92 per cent of iron, some 7 per cent of nickel (common in meteoric iron), traces of cobalt (also common in meteoric iron), silicon, sulphur, phosphorus, carbon, iridium, and platinum, as well as traces of a few other elements. Troilite, a sulphide of iron, found only in meteorites, occurs. Silicon carbide (moissanite) occurs in this iron, and for a time was not known to occur elsewhere in nature. Silicon carbide is manufactured under the trade name of "Carborundum," at Niagara Falls, New York. It is next to diamond in hardness, with the exception of boron carbide. Probably correlated with the silicon carbide is the occurrence of diamonds, all extremely small. As stated in Dr. Toothaker's letter quoted above, Dr. G. A. Koenig, Professor of Chemistry in the University of Pennsylvania, was the first to isolate diamonds from this meteoric iron, and this was in 1891. These diamonds were very small, one mentioned in the report having a diameter of one-half millimeter. The material analyzed was from a forty-pound meteorite brought from Meteor Crater by Dr. A. E. Foote of Philadelphia, who, in this same year, was the first to bring this crater prominently before the scientific world. Later five diamonds were secured from this iron by Dr. J. W. Mallet, F.R.S., Professor of Chemistry, University of Virginia. It was thought that the platinum, along with the nickel, would promise a profitable commercial enterprise. In fact, it was this idea that prompted the mining ventures and the explorations which have given us sc much interesting information. Considering its composition, it is not surprising to know that the late Dr. George P. Merrill, Head Curator of Geology in the U. S. National Museum, and one of the leading authorities on Meteorites, stated that Canyon Diablo iron is one of the hardest and toughest of all known meteoric irons.

Widmanstättian lines

When polished and etched with nitric acid, the Canyon Diablo iron shows definite and

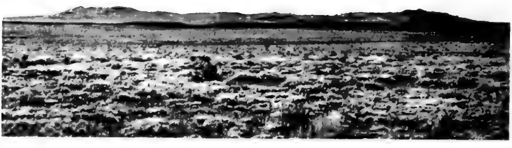
Photograph from Yerkes Observatory

Craters of the Moon

Above: The moon at gibbous phase between first quarter and full, showing many of the 30,000 craters on the side which is always turned toward the earth. The similarity of these lunar craters to Meteor Crater in Arizona is evident

Below: The elevated rim of Meteor Crater from a distance of two or three miles. It varies in height from 130 to 160 feet

Photograph by Clyde Fisher



Photograph by Clyde Fisher

Right: Meteor Crater, blanketed with snow, as seen from a plane; San Francisco Peaks, from forty to fifty miles distant, are shown in the background; Canyon Diablo, about three miles to the westward, may be seen in the middle ground

Meteor Crater

Below:
Meteor Crater from a plane on an early summer morning. The automobile road connecting U. S. Highway 66 with the north rim shows in the lower right-hand corner

Photograph by Clyde Fisher

pronounced Widmannstättian figures. These are the geometrical markings on the polished surface which are caused by internal crystallization. In this form they are found only in meteorites.

Besides the unoxidized meteoric iron, there have been found at the Crater many so-called "shale-balls", which are generally rounded or globular masses of disintegrating meteoric iron and nickel oxide, many of them containing solid nickel-iron centers. The late Professor O. C. Farrington, who was certainly one of the greatest students of meteorites, believed the shale-balls to be the result of terrestrial oxidation, and not that oxidation occurring when passing through the air.

More than one hundred shale-balls have been found, the heaviest weighing more than forty pounds. Some contain microscopic diamonds. Besides the typical shale-balls there are in and about the crater great quantities of oxidized iron-shale, which without much doubt came from shale-balls. This gives a suggestion as to the fate of some of the Meteor Crater iron. That most of these irons are the residuals of shale-balls, was the confident opinion of Mr. D. M. Barringer, who pointed out that the rounded shape of the latter was probably due to the gentle abrasive action of the members of the cluster during their years of journeying through space.

In determining the origin of the crater, the composition of the elevated rim is significant. This rim, which is 130 to 160 feet higher than the surrounding plain, and one and one-half miles in outside diameter, can easily be seen from more than ten miles away. It is made up largely of boulders and smaller fragments of Kaibab limestone and Coconino sandstone. Some huge boulders were ejected from the crater and thrown over the rim to the distance of a mile or more. It is true, of course, that the ejected boulders occur more abundantly as one approaches the crater.

Much of the Coconino sandstone has been reduced to a fine rock-flour, so fine that it requires a microscope to show that it consists of shattered or pulverized sand-grains. This rock-flour or "star-dust," as it has been called, composes a great part of the rim, nearly three miles in circumference, and it has also been found 850 feet deep in the crater. There are literally millions of tons of this fine powder, white as snow. It is estimated that it constitutes 15 to 20 per cent of all material thrown out by the impact.

Of all the evidence that Meteor Crater was caused by impact, perhaps the most convincing to geologists is the fact that some of the Coconino sandstone was changed into a vesicular, metamorphosed rock, looking not unlike pumice stone and very light. In fact the quartz has been fused and is now amorphous and not crystalline. This silica-glass or fused quartz has been named by the mineralogists "Le Chatelierite."

Exploded theories

The limestone-sink theory could not explain the elevated rim made up of boulders, fragments and rock-flour. It could not explain the presence of rock-flour and fused quartz at all. It could not explain the presence, in the rim, of Coconino sandstone boulders which came from a stratum that underlies the Kaibab limestone.

A steam blow-out theory might account for the rock-flour, although this seems to the writer extremely doubtful, but it seems certain that no scientist would maintain that it is competent to account for the silica-glass or Le Chatelierite. Dr. George P. Merrill states that there is no record of a sudden outburst of volcanic action wherein the heat generated was sufficient to fuse crystalline quartz. The steam blow-out theory is further weakened by the fact that there are no igneous or eruptive rocks in or around the Crater or in the neighborhood, and by the fact that there is no evidence of solfataric activity, and by the finding of unaltered sandstone (Supai) in place in the bottom of the crater in its proper stratigraphical position, shown by the cores of numerous drill-holes sunk in the floor of the crater.

Probability

The fact that the crater is in the center of a meteor fall, would be looked upon as a coincidence by the advocates of both the limestone-sink theory and the steam blow-out theory. But the finding of meteoric material mixed with the ejected rock, and underneath the lake deposits in the bottom of the crater, and

Photograph by Clyde Fisher

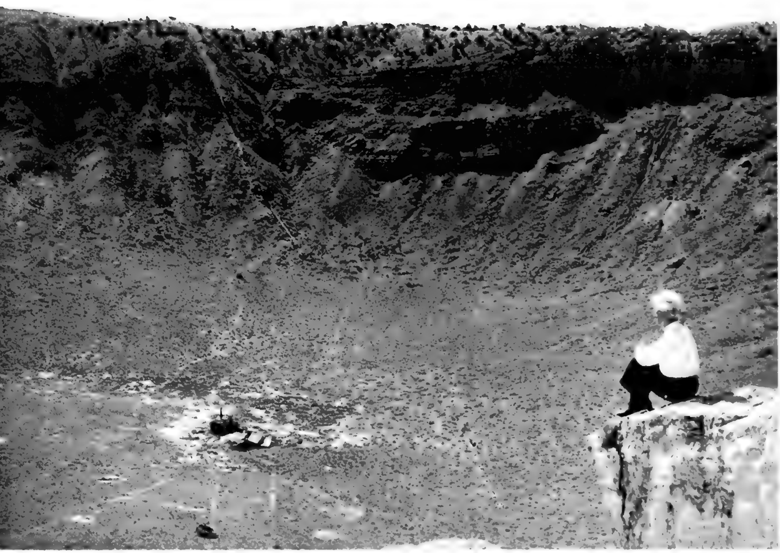
Right:
Meteor Crater in Arizona, located about twenty miles west of Winslow and thirty-five miles east of Flagstaff, photographed from a plane in winter, when snow covered the landscape, including the bottom of the crater

Photograph by Ruth Anna Fisher

Left: Clyde Fisher with Jack Irish, the pilot on his first flight over Meteor Crater

Below: Clyde Fisher surveying the Crater from the north rim. Note the sizable buildings of the mining company on the crater floor

Photograph by Clyde Fishe



even 500 or 600 feet below the crater floor, indicates that the meteor fall occurred at the same time that the crater was formed, that is, that the excavated material and the meteorites got there at the same time. The probability that these two unusual phenomena occurred at the same time and at the same place is infinitesimal.

The question that naturally arises is how large a mass of meteoric iron would be necessary to produce the result,—to plow into solid rock and form a crater about four-fifths of a mile in diameter and nearly 600 feet deep!

It has been variously estimated that the mass of meteoric iron weighed from 100,000 tons to as much as 10,000,000 tons, that it was several hundred feet in diameter if the larger estimates are correct, and that it was moving from seven to forty miles a second.

The amount of rock dislodged and partly thrown out of the crater has been estimated at over 300,000,000 tons. The true crater is filled to one-half its depth with rock fragments which rolled or fell back.

On the bottom of Meteor Crater there are now 70 to 90 feet of lacustrine or lake sediments formed when this was a small lake. In these deposits many fossil shells were found, which were identified by Dr. William H. Dall, Curator, Division of Mollusks, U. S. National Museum, as "all recent species local to the region of southwestern United States."

While it is now true that practically all astronomers, physicists and geologists agree that this crater was caused by the impact of a huge mass of meteoric iron, the testimony of a few of the leading scientists in these fields, given before such unanimity of opinion had been reached, would not be out of place. Following are verbatim statements from a few:

Dr. Elihu Thomson, Director of the Thomson Laboratory of the General Electric Company,—"There can be no question of the Crater being made by masses of meteoric iron, and that an enormous mass of such iron remains buried under the south wall of the Crater."

Dr. W. F. Magie, former head of the Palmer Physical Laboratory, and Dean of the Faculty of Princeton University, who spent two weeks at the Crater making careful studies;—"There is no reasonable doubt that the Crater was formed by the fall of a meteor and this meteor is buried in it."

Dr. Henry Norris Russell, Head of the Department of Astronomy, Princeton University,—"I have examined the Crater on the ground, as well as the other evidence, and I am thoroughly convinced of its meteoric origin."

Position of meteorite

If this crater was formed by impact, where is the main mass of the meteoric iron? Mr. Barringer and his associates first attempted to answer this question by drilling some twenty-five holes in the floor of the crater. These holes were drilled in the bottom of the crater because it was then believed that the nearly circular shape of the crater indicated that the meteorite had descended vertically or nearly so. No large piece of meteoric material was ever struck in these holes. Mr. Barringer's son, Daniel Moreau Barringer, Jr., tells us how his father was accidentally led to the discovery that the fall of this meteorite was not vertical, but at an angle. The son writes as follows: "Largely by accident, my father observed one day that by firing a rifle into mud he could make an excellent replica of the Crater, and, moreover, that the rifle need not be fired vertically downward, but might be held even less than 45 degrees from the horizontal. Naturally one would suppose that a shot at such an angle would make an elongated hole. But it will not. The hole will be just as round as though the shot had come straight down, although the projectile will lodge under one edge of the hole instead of in the center. A charge of shot fired from a shotgun at close range will produce the same effect." This observation led the elder Mr. Barringer to make a closer examination of the crater, the results of which indicated with great certainty that the mass had come from the north at a comparatively low angle.

Thereupon a drill-hole some 1400 feet deep was sunk on the south rim. Beginning at a depth of 1000 feet, a series of hard bodies carrying nickel, and clearly meteoric in origin, were struck. Of this boring, Mr. Barringer reported, "Eventually this hole (the last boring sunk through the south rim, it having been determined that the mass approached from the

north at an angle of approximately 45°) encountered what is beyond doubt the upper part of the buried cluster of iron meteorites, finding it exactly in the predicted position." It is significant that geophysical investigations, both magnetic and electrical, as well as the geological evidence, all pointed to a large mass of meteoric iron under the southern rim; and two recent drill-holes in the southwestern part of the bowl about 1000 feet from the previous drill-hole on the rim, have also encountered numerous meteorites.

Volatilization?

It has been suggested that the energy of onward motion, when the meteoric body was suddenly stopped, would have been transformed into sufficient heat to vaporize all or part of the main body. Mr. Barringer believed, however, that due largely to being checked by the air, the meteoric body struck at too low a velocity to have been vaporized. The absence of stains, such as would be caused by the vapor which would have been formed by volatilization of the iron, he believed, strongly supported this view.

Dr. F. R. Moulton, formerly Professor of Astronomy in the University of Chicago, co-author of the Planetesimal Hypothesis, and leading student of celestial mechanics, arrived at the following conclusions:

"My interpretation of the probable event is roughly as follows: The dense part of the swarm was something like 2,000 feet in diameter and its mass was from 100,000 to 500,000 tons. It crashed into the rock to a depth of something like 800 to 1000 feet, carrying with it a large mass of greatly condensed (and consequently heated) air, which was further condensed on penetrating the rock. Ejected rock was thrown out not only by the condensed air and the steam generated, but also by volatilization of a considerable amount of the meteor and rock materials with which it came in contact."

Explosion?

Dr. Moulton discusses the fate of meteors of various masses in his ASTRONOMY (1931), closing with the following sentences: "But a meteorite weighing thousands of tons would not be greatly retarded by the air and would strike the surface at a high velocity. At a speed of 20 kilometers per second the resistance of surface soil or rock, due to its inertia alone, would amount to 32×10^9 grams per square centimeter; at 14 kilometers per second the resistance would be about half as great. Either of these pressures would be sufficiently great to cause the material of the meteorite to flow as though it were a gas. The energy given up in a tenth of a second would be sufficient to vaporize both the meteorite and the material it encountered—there would be in effect a violent explosion that would produce a circular crater, regardless of the direction of impact, which alone would remain as evidence of the event." The recent studies of Professor C. C. Wylie, of the University of Iowa, on the explosive effects of high-speed bullets upon striking a target evidently support the conclusions of Dr. Moulton. The stubborn reply to these theoretical conclusions, however, is the fact that thousands of meteorites of the original mass, several of which are mentioned on pages 4 and 5, *did remain* about the crater.

An inevitable question arises: What is the age of Meteor Crater? It is certainly young, geologically speaking. The sharp angles of the boulders and smaller fragments in the rim and talus indicate that. A Juniper tree growing on the south rim is said to put it back at least 700 years, because it had that number of annual rings. The presence of lapilli and volcanic ash found in the lake deposits in the bottom of the crater correlate it with the last volcanic eruptions in the nearby mountains of Arizona. These, together with other evidences of the lake deposits, etc. point to a probable age of 40,000 to 75,000 years,—a conclusion arrived at by Dr. Eliot Blackwelder, Professor of Geology in Stanford University, who has made careful studies on two visits to the crater.

Craters of the moon

A comparison of Meteor Crater with the craters on the moon has led some scientists to believe that the latter were also caused by impact. While it is probably true that the majority of astronomers accept the volcanic theory of the origin of the moon's craters, there is much evidence in favor of the impact theory.

The difference in opinion among scientists

Above: The Hoba Meteorite. The largest known meteorite, located near Grootfontein, S. W. Africa, estimated to weigh from 50 to 70 tons. The second person from the left is Dr. L. J. Spencer, who has charge of the meteorites in the British Museum of Natural History.

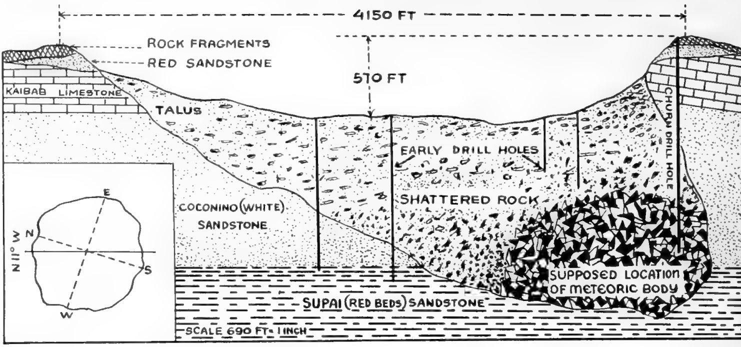
Below: The Ahnighito Meteorite. The Ahnighito, weighing 36½ tons, the largest meteorite in any museum, brought from Greenland in 1897 by Peary. Three other large iron meteorites, pretty surely of the same fall as the Ahnighito, were found nearby. Pieces of one of these had been laboriously hammered off by the Eskimos for knives.

From Tenth Annual Report of the Bureau of Ethnology.

Above: SIOUX CALENDAR SHOWING METEOR SHOWER. The Winter Count of Lone Dog, a Sioux warrior, showing the Leonid meteor shower of November, 1833,—when "the stars fell", as the Indians all agreed. The record is in the middle of second coil of the spiral from the bottom. In the original, in the Smithsonian Institution the crescent moon is black and the meteors are red. (See cut on page 2.)

Below: BOULDERS IN THE WALL OF METEOR CRATER. Portion of the wall of the crater showing some of the larger boulders left as a result of the impact.

Photograph by Clyde Fisher



can well be illustrated by the fact that the authors of the Planetesimal Hypothesis of the origin of the Solar System disagree. Professor T. C. Chamberlin was definitely opposed to the impact theory for the origin of the lunar craters, while Professor F. R. Moulton says that these craters may have been caused by the impact of planetesimals.

Some of the difficulties with the volcanic theory are as follows: volcanic craters on the earth are far less numerous than the craters on the moon, and yet the former belong to several types, while nearly all of those on the moon show great similarity, none on the earth being like the typical craters on the moon.

There are 30,000 craters on this side of the moon, and yet not a single lava-flow can be seen. There are no fissures on the moon from which lava has flowed.

As pointed out by Mr. D. M. Barringer, in his thorough-going work on this subject, there is not a single conical mountain peak on the moon which is similar to Fuji, Aetna, Vesuvius, Orizaba and other volcanoes of this type, made by the effusion of lava from a central vent and the building up of the mountain mass higher and higher as it flows down the sides.

Volcanic craters on the earth do not have central conical hills like those in so many of the lunar craters.

Finally the fact that the moon is not large enough ever to have held an atmosphere indicates that it could never have had enough water or oxygen to cause either the types of volcanic craters found on the earth or the far more abundant craters on the moon. Scientists who have studied volcanism hardly need to assure us, as they unanimously do, that there can be no volcanic phenomena in the absence of water and oxygen.

On the other hand, the impact theory, set forth by Richard A. Proctor in his book entitled "The Moon," has other facts in its favor.

The floors of the craters on the moon, as Mr. Barringer has stated, are usually far below the surrounding surface, as is true in Meteor Crater in Arizona, whereas the floor of a terrestrial volcanic crater is usually above the original surface surrounding the volcano.

The only explanation that has come to the writer's knowledge for the formation of the rift through the lunar Alps is that it may have been caused by a huge meteorite or planetesimal which struck the moon tangentially.

The central peaks

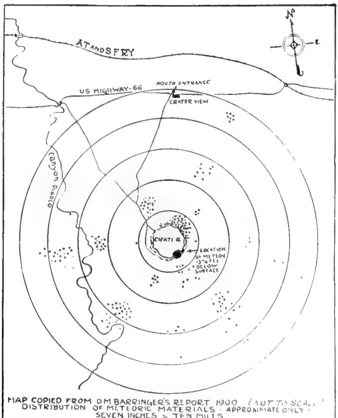
The central conical hills furnish strong evidence of the impact theory of the origin of the craters on the moon, as a study of splashes has shown. This is made clear by high-speed motion pictures of drops of liquids or, of small solid bodies, falling into liquids at rest. It is also shown by miniature craters produced by shooting bullets, or charges of shot from a shotgun at close range, into mud or other plastic media. At first, the circular shape of the craters on the moon did not seem to fit in with

this theory, but experiment has shown that the craters would be circular even when the projectile arrives at a rather low angle.

The impact theory would explain the light-colored streaks which radiate from the craters Copernicus, Tycho, and others, in that they are probably made of rock-flour produced in exactly the same way as that at Meteor Crater in Arizona, and splashed out at the time of the impact. The great length of these streaks on the moon, and also the large size of the lunar craters are probably correlated with the small surface gravity on the moon, which is about one-sixth that on the earth, and with the absence of atmosphere on the moon.

The fact that there are so few impact craters on the earth as compared with those on the moon,—assuming that those on the moon were caused by impact,—is probably due to erosion. Water erosion, wind erosion, freezing and thawing, etc., have been active on the earth for millions of years, while on the moon, since there is no water and no air, there has been no erosion, except that very slight effect caused by the impact of meteors in the absence of the cushion of air, as pointed out in his book entitled "Meteors" (p. 254), by Dr. Charles P. Olivier, Professor of Astronomy in the University of Pennsylvania and President of the American Meteor Society.

Until recently it was believed that Meteor Crater was the only one of its kind on the face of the earth, while there are 30,000 on the side of the moon turned toward the earth. But more and more are being identified on the earth. The meteorite craters so far studied are distributed as follows: one near Winslow, Arizona; one near Odessa, Texas, identified as a meteor crater by Mr. Daniel Moreau Barringer, Jr.; one near Haviland, Kiowa County, Kansas, identified as a meteor crater by Professor H. H. Nininger; a group of some thirteen near Henbury in Central Australia; a group of six craters on the Baltic island of Saaremaa (Oesel) belonging to Estonia, which the writer had the opportunity of visiting in the summer of 1936, identified as meteor craters by Mr. I. Reinvald in 1927; the Wabar craters in Arabia; the Siberian craters; a doubtful one at Ashanti, in West Africa; a very doubtful group near the coast of South Carolina; a supposed crater in Persian Baluchistan; and the



MAP SHOWING DISTRIBUTION OF METEORIC MATERIALS AROUND METEOR CRATER

Campo del Cielo craters in Argentina. No meteorites have been found at the Estonian craters, none at the Siberian craters, and none at the South Carolinian craters.

Certainly no other meteor crater has been so thoroughly studied as the one in Arizona, and judging from a comparison of these studies with the published descriptions of meteor craters in other parts of the world, certainly none is more interesting or impressive.

Our poet-astronomer, William Tyler Olcott, has paid tribute to this gigantic bowl in the following lines, titled "Meteor Crater, Arizona."

You were a black moth winging through the night,
A bit of cosmos shorn from molten matter,
One of a swarm with beating wings that batter
The source and all reflections of the light.

You were the silent echo of a voice,
A slave to might beneath the lashes bending,
And then you plunged to death in flames descending,
In answer to predestinated choice.

You now within a mausoleum lie,
And men gaze on your sepulchre in wonder,
Far down beneath the earth you rent asunder.
You rest secure and dream of star and sky.

METEOR CRATER, ARIZONA

by

CLYDE FISHER

5.06

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GUIDE LEAFLET SERIES, No. 92
First Edition Revised

The American Museum of Natural History
New York, New York
1941

METEOR CRATER, ARIZONA

By CLYDE FISHER

Curator of Astronomy and Curator-in-Chief of the Hayden Planetarium
American Museum of Natural History

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THE METEOR SHOWER OF 1833.

An old wood-cut from Grondal's "*Music of the Spheres*" illustrating the Leonid shower of November 13, 1833, the greatest phenomenon of the kind on record. Compared to a fall of snowflakes. (See cut at top of page 13.)

Meteor Crater, Arizona

Where a huge, dense mass of iron meteorites struck the earth, probably 50,000 years ago, the impact of which crushed and dislodged some 300,000,000 tons of rock

By Clyde Fisher,

Curator of Astronomy and Curator-in-Chief of the Hayden Planetarium, American Museum of Natural History

A METEOR shower is one of the most impressive phenomena in the whole realm of nature. Its sudden appearance, together with the suggestion of falling or shooting stars, excites wonder and fear, especially in untutored and primitive minds. Various tribes of American Indians used the November shower of 1833, the greatest meteor shower on record,—"the rain of stars,"—as a milestone in their calendars.

While showers or swarms of meteors are comparatively infrequent, the adventitious or occasional meteors are extremely common. It is estimated that about 100,000,000,000 meteors and micrometeors enter the earth's atmosphere every twenty-four hours. Most of these are exceedingly small, weighing perhaps only a few grains each. When we recall that there are 7,000 grains in a pound, avoirdupois, we realize how tiny these meteors must be. Practically all of the meteors that penetrate the earth's atmosphere, day after day, are burned up due to the heat generated by friction with the air, and consequently do not reach the earth.

Few fall to the earth

Occasionally, of course, one comes clear through to the earth, and, if found, it is called arbitrarily a "meteorite", the name "meteor" usually being reserved for those which enter the earth's atmosphere, but which do not come through to the earth. Nearly 1,350 falls of meteorites are known, of which more than 550 are represented in the collections of the American Museum of Natural History.

Half the falls observed

Although nearly 500 falls of meteorites have actually been observed, the phenomenon still attracts much attention,—and well it might, for these are the only direct messengers from space that come to the earth, the only heavenly bodies besides the earth that we can actually touch. A recent fall to be observed was that of July 1, 1933, when two masses of stony meteorite were seen to fall near Spartanburg, South Carolina, one weighing about twelve pounds and the other about half as much. This fall occurred in the daytime, and was observed by several persons.

During the last few years it seems that more than the usual number of large meteors, sometimes called fire-balls, have been observed. On March 24, 1933, a gigantic meteor flashed across five southwestern states. An airmail pilot flying near Amarillo, Texas, declared that it looked as big as the hangar at the Wichita Airport. Some most unusual and striking photographs of the train left by this fire-ball were secured at Timpas, Colorado, by Mr. C. R. West. In northeastern New Mexico Mr. Charles M. Brown succeeded in photographing the meteor, which showed a cork-screw train at the moment,—securing an absolutely unique photograph. Dr. H. H. Nininger succeeded in locating a number of pieces of this fall in northeastern New Mexico, along a line twenty-nine miles long, for which success he deserves much credit. It proved to be a stone meteorite or rather a group of meteorites, one specimen of which, picked up near Pasamonte, New Mexico, has been acquired from Dr. Nininger for the collections of the American Museum of Natural History. On September 27, 1934, another huge meteor was observed in California by an airplane pilot who thought it

necessary to swerve his plane to keep from colliding with it. In this case no meteoric material constituting a fall has been located. On July 11, 1939, just at dusk, a brilliant fire-ball startled the residents of several northern states from Wisconsin to Pennsylvania, and also Ontario, Canada. Practically the entire town of Dresden, Ontario saw this meteor fall. It consisted of several fragments of stone, now known as the Dresden meteorite.

Most great falls prehistoric

The greatest falls of meteoric material known on the face of the earth were not observed. In fact, with the exception of the Siberian fall of June 30, 1908, all of these occurred without much doubt in prehistoric times. The first crater, the cause of which was determined to be due to the impact of a meteorite or mass of meteorites, was Meteor Crater in Arizona. It was not until the early years of this century that the theory that this crater was caused by the impact of meteoric or cometary material was set forth by Mr. Daniel Moreau Barringer, geologist and mining engineer of Philadelphia, and to him must be given the credit for convincing scientists of the truth of his theory.

Meteor Crater is best seen from the air, and consequently the most satisfactory photographs have been made from an airplane. A huge circular crater, nearly a mile in diameter and nearly six hundred feet deep, with a conspicuous elevated rim, formed in solid limestone and sandstone, constitutes an impressive challenge to one's innate desire to understand the causes of things. Svante Arrhenius, the great Swedish scientist, author of the electrolytic theory of matter, is said to have declared that Meteor Crater is the most interesting spot on Earth.

Located in Coconino County, in north-central Arizona, about twenty miles west of Winslow and thirty-five miles east of Flagstaff, the crater is easily reached by the Santa Fé Railroad or by U. S. Highway 66.

First seen by white men some sixty years ago, although doubtless known to the Indians long before, it was formerly known as Coon Butte or Coon Mountain, the latter part of the name referring to the elevated rim.

Dr. Charles R. Toothaker, Curator of the Philadelphia Commercial Museum, who had much to do with the Meteor Crater iron in the early days, writes me as follows:

"It appears that in 1886 some shepherds were in the neighborhood of Cañon Diablo, Arizona, and one of them named Mathias Armijo found a piece of this iron and thought it was silver. Some time later, a man staked a claim and put the samples in the hands of a chemical firm named M. B. Booth & Co., in Albuquerque, New Mexico, in March 1891.

"Dr. A. E. Foote of Philadelphia was at that time a dealer in mineral specimens and I was employed by him. I remember when the first news of this matter reached Dr. Foote. He went to Cañon Diablo at once and sent back a piece of the iron which was immediately put in the hands of Professor G. A. Koenig, Professor of Chemistry in the University of Pennsylvania. Koenig analyzed it and discovered diamonds in this iron."

Crater at first misunderstood

This crater was at first explained by the scientists of the U. S. Geological Survey as the result of a steam or gaseous blow-out. Because of the absence of lava and other evidence of volcanism, no scientists have believed it to be a volcanic crater. One writer advanced the theory that it was a limestone-sink. But the credit for the conception and establishment of the theory that is now well-nigh universally accepted goes to Mr. Barringer,—and a magnificent conception it was. He set forth the idea that this crater was the result of the impact of a huge, dense mass of iron meteorites, possibly the head of a small comet, and this theory has now come to be held by nearly all geologists, physicists and astronomers.

This meteoric mass penetrated 40 to 50 feet of purplish-red sandstone (Moencopie Formation—Triassic), which lies next below the thin soil of the surrounding plain; then crashed through some 300 feet of Kaibab Limestone (Permian Age), the same rock that outcrops in the Grand Canyon of the Colorado in northwestern Arizona, then it plowed into the Coconino Sandstone (Permian Age), which underlies the Kaibab Limestone, shattering this

stratum to a depth of some 600 feet, or practically to the Supai Sandstone or "Red Beds" (Permian) underneath.

The meteoric origin of the Crater is suggested by the occurrence of literally thousands of pieces of meteoric iron around the crater. These fragments were found as far as four or five miles from the crater on all sides, but the nearer the Crater, the more numerous they were. In other words, Meteor Crater is about in the exact center of an area from which have been collected many more specimens of meteoric iron than have ever been found on all of the rest of the earth's surface.

The larger specimens

The largest piece of which I have knowledge is in the Colorado Museum of Natural History in Denver, and it weighs 1,406 pounds. For this information I am indebted to Dr. H. H. Nininger, Curator of Meteorites in that Museum. The second-largest piece is in the American Museum of Natural History and weighs 1,055 pounds (re-weighed in 1935 upon removal into the Hayden Planetarium). The third-largest piece, now in the Field Museum of Natural History, weighs 1,013 pounds, according to the late Dr. O. C. Farrington, Curator of Geology in that Museum. The fourth-largest piece of which I have knowledge is in the Smithsonian Institution collection in charge of Mr. E. P. Henderson, Assistant Curator of Physical Geology. It is labeled and recorded as weighing 1,000 pounds. Mr. Henderson informs me that they also have in their collection another piece weighing 960 pounds and still another weighing 746 pounds, besides a great many others of lesser weight. Another large piece is located near the front door of the Fred Harvey Indian Building in Albuquerque, New Mexico, which, according to Mr. H. Schweizer, weighs 625 pounds. It is estimated that between ten and fifteen tons of meteoric iron have been shipped away from Meteor Crater, all of which has been collected within about five miles of the crater, most of it in the immediate vicinity.

Meteorites have been known to burst in the air just before striking the earth, but very few, if any, of the individual pieces of Meteor Crater iron, whether large or small, show evidence of the bursting in air of an enormous meteorite. For this reason it is believed that the crater was formed by a huge meteorite accompanied by thousands of small ones, or more probably by a huge, dense mass of comparatively small, iron meteorites.

It is noteworthy, according to Russell, Dugan and Stewart "*Astronomy*," (p. 455), that nearly every one of the large iron meteorites found on the earth's surface lies on the side of our planet which, at the time of the great impact, faced in the direction from which this swarm came. They *may* all have belonged to one large swarm.

Composition

The meteoric iron from the vicinity of Meteor Crater, known as Canyon Diablo iron, named from a gorge located about three miles to the westward, is remarkable in its composition, for it contains 91 to 92 per cent of iron, some 7 per cent of nickel (always present in meteoric iron), traces of cobalt (also common in meteoric iron), silicon, sulphur, phosphorus, carbon, iridium, and platinum, as well as traces of a few other elements. Troilite, a sulphide of iron, found only in meteorites, occurs. Silicon carbide (moissanite) occurs in this iron, and for a time was not known to occur elsewhere in nature. Silicon carbide is manufactured under the trade name of "Carborundum," at Niagara Falls, New York. It is next to diamond in hardness, with the exception of boron carbide. Probably correlated with the silicon carbide is the occurrence of diamonds, all extremely small. As stated in Dr. Toothaker's letter quoted above, Dr. G. A. Koenig, Professor of Chemistry in the University of Pennsylvania, was the first to isolate diamonds from this meteoric iron, and this was in 1891. These diamonds were very small, one mentioned in the report having a diameter of one-half millimeter. The material analyzed was from a forty-pound meteorite brought from Meteor Crater by Dr. A. E. Foote of Philadelphia, who, in this same year, was the first to bring this crater prominently before the scientific world. Later five diamonds were secured from this iron by Dr. J. W. Mallet, F.R.S., Professor of Chem-

Photograph from Yerkes Observatory

Craters of the Moon

Above: The moon at gibbous phase between first quarter and full, showing many of the 30,000 craters on the side which is always turned toward the earth. The similarity of these lunar craters to Meteor Crater in Arizona is evident

Below: The elevated rim of Meteor Crater from a distance of two or three miles. It varies in height from 130 to 160 feet

Photograph by Clyde Fisher

Photograph by Clyde Fisher

Right: Meteor Crater, blanketed with snow, as seen from a plane; San Francisco Peaks, from forty to fifty miles distant, are shown in the background; Canyon Diablo, about three miles to the westward, may be seen in the middle ground

Meteor Crater

Below: Meteor Crater from a plane on an early summer morning. The automobile road connecting U. S. Highway 66 with the north rim shows in the lower right-hand corner

Photograph by Clyde Fisher

istry, University of Virginia. It was thought that the platinum, along with the nickel, would promise a profitable commercial enterprise. In fact, it was this idea that prompted the mining ventures and the explorations which have given us so much interesting information. Considering its composition, it is not surprising to know that the late Dr. George P. Merrill, Head Curator of Geology in the U. S. National Museum, and one of the leading authorities on Meteorites, stated that Canyon Diablo iron is one of the hardest and toughest of all known meteoric irons.

Widmannstättian lines

When polished and etched with nitric acid, the Canyon Diablo iron shows definite and pronounced Widmannstättian figures. These are the geometrical markings on the polished surface which are caused by internal crystallization. In this form they are found only in meteorites.

Besides the unoxidized meteoric iron, there have been found at the Crater many so-called "shale-balls", which are generally rounded or globular masses of disintegrating meteoric iron and nickel oxide, many of them containing solid nickel-iron centers. The late Dr. O. C. Farrington, one of the leading students of meteorites, believed the shale-balls to be the result of terrestrial oxidation, and not that of oxidation occurring when passing through the air.

More than one hundred shale-balls have been found, the heaviest weighing more than forty pounds. Some contain microscopic diamonds. Besides the typical shale-balls there are in and about the crater great quantities of oxidized iron-shale, which without much doubt came from shale-balls. This gives a suggestion as to the fate of some of the Meteor Crater iron. That most of these irons are the residuals of shale-balls, was the confident opinion of Mr. D. M. Barringer, who pointed out that the rounded shape of the latter was probably due to the gentle abrasive action of the members of the cluster during their years of journeying through space.

In determining the origin of the crater, the composition of the elevated rim is significant. This rim, which is 130 to 160 feet higher than the surrounding plain, and one and one-half miles in outside diameter, can easily be seen from more than ten miles away. It is made up largely of boulders and smaller fragments of Kaibab limestone and Coconino sandstone. Some huge boulders were ejected from the crater and thrown over the rim to the distance of a mile or more. It is true, of course, that the ejected boulders occur more abundantly as one approaches the crater.

Much of the Coconino sandstone has been reduced to a fine rock-flour, so fine that it requires a microscope to show that it consists of shattered or pulverized sand-grains. This rock-flour or "star-dust," as it has been called, composes a great part of the rim, nearly three miles in circumference, and it has also been found 850 feet deep in the crater. There are literally millions of tons of this fine powder, white as snow. It is estimated that it constitutes 15 to 20 per cent of all material thrown out by the impact.

Of all the evidence that Meteor Crater was caused by impact, perhaps the most convincing to geologists is the fact that some of the Coconino sandstone was changed into a vesicular, metamorphosed rock, looking not unlike pumice stone and very light. In fact the quartz has been fused and is now amorphous and not crystalline. This silica-glass or fused quartz has been named by the mineralogists "Le Chatelierite."

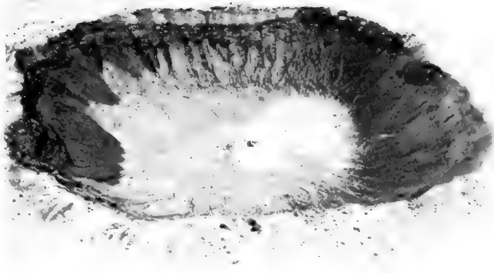
Exploded theories

The limestone-sink theory could not explain the elevated rim made up of boulders, fragments and rock-flour. It could not explain the presence of rock-flour and fused quartz at all. It could not explain the presence, in the rim, of Coconino sandstone boulders which came from a stratum that underlies the Kaibab limestone.

A steam blow-out theory might account for the rock-flour, although this seems to the writer extremely doubtful, but it seems certain that no scientist would maintain that it is competent to account for the silica-glass or Le Chatelierite. Dr. George P. Merrill states that there is no record of a sudden outburst of volcanic action wherein the heat generated was sufficient to fuse crystalline quartz. The steam blow-out

Photograph by Clyde Fisher

Right:
Meteor Crater in Arizona, located about twenty miles west of Winslow and thirty-five miles east of Flagstaff, photographed from a plane in winter, when snow covered the landscape, including the bottom of the crater

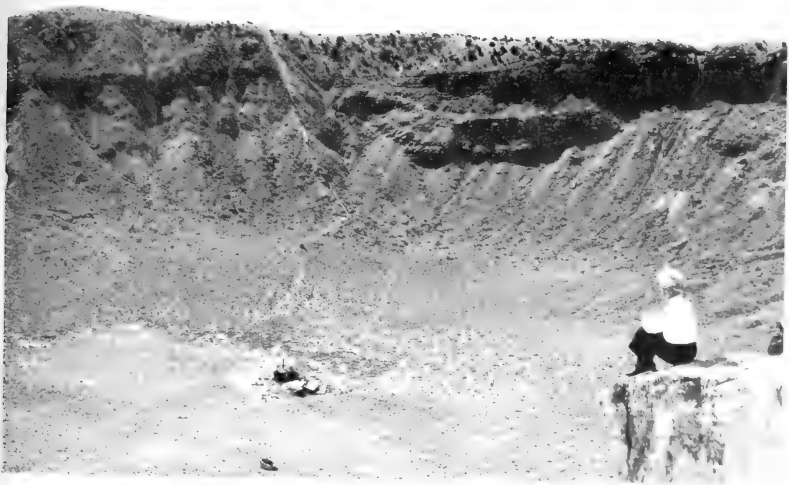


Photograph by Ruth Anna Fisher

Left: Clyde Fisher with Jack Irish, the pilot on his first flight over Meteor Crater

Below: Clyde Fisher surveying the Crater from the north rim. Note the sizable buildings of the mining company on the crater floor

Photograph by Te Ata



theory is further weakened by the fact that there are no igneous or eruptive rocks in or around the Crater or in the neighborhood, and by the fact that there is no evidence of solfataric activity, and by the finding of unaltered sandstone (Supai) in place in the bottom of the crater in its proper stratigraphical position, shown by the cores of numerous drill-holes sunk in the floor of the crater.

Probability

The fact that the crater is in the center of a meteor fall, would be looked upon as a coincidence by the advocates of both the limestone-sink theory and the steam blow-out theory. But the finding of meteoric material mixed with the ejected rock, and underneath the lake deposits in the bottom of the crater, and even 500 or 600 feet below the crater floor, indicates that the meteor fall occurred at the same time that the crater was formed, that is, that the excavated material and the meteorites got there at the same time. The probability that these two unusual phenomena occurred at the same time and at the same place is infinitesimal.

The question that naturally arises is how large a mass of meteoric iron would be necessary to produce the result,—to plow into solid rock and form a crater about four-fifths of a mile in diameter and nearly 600 feet deep!

It has been variously estimated that the mass of meteoric iron weighed from 100,000 tons to as much as 10,000,000 tons, that it was several hundred feet in diameter if the larger estimates are correct, and that it was moving from seven to forty miles a second.

The amount of rock dislodged and partly thrown out of the crater has been estimated at over 300,000,000 tons. The true crater is filled to one-half its depth with rock fragments which rolled or fell back.

On the bottom of Meteor Crater there are now 70 to 90 feet of lacustrine or lake sediments formed when this was a small lake. In these deposits many fossil shells were found, which were identified by Dr. William H. Dall, Curator, Division of Mollusks, U. S. National Museum, as "all recent species local to the region of southwestern United States."

While it is now true that practically all astronomers, physicists and geologists agree that this crater was caused by the impact of a huge mass of meteoric iron, the testimony of a few of the leading scientists in these fields, given before such unanimity of opinion had been reached, would not be out of place. Following are verbatim statements from a few:

Dr. Elihu Thomson, Director of the Thomson Laboratory of the General Electric Company,—"There can be no question of the Crater being made by masses of meteoric iron, and that an enormous mass of such iron remains buried under the south wall of the Crater."

Dr. W. F. Magie, former head of the Palmer Physical Laboratory, and Dean of the Faculty of Princeton University, who spent two weeks at the Crater making careful studies;—"There is no reasonable doubt that the Crater was formed by the fall of a meteor and this meteor is buried in it."

Dr. Henry Norris Russell, Head of the Department of Astronomy, Princeton University,—"I have examined the Crater on the ground, as well as the other evidence, and I am thoroughly convinced of its meteoric origin."

Position of meteorite

If this crater was formed by impact, where is the main mass of the meteoric iron? Mr. Barringer and his associates first attempted to answer this question by drilling some twenty-five holes in the floor of the crater. These holes were drilled in the bottom of the crater because it was then believed that the nearly circular shape of the crater indicated that the meteorite had descended vertically or nearly so. No large piece of meteoric material was ever struck in these holes. Mr. Barringer's son, Daniel Moreau Barringer, Jr., tells us how his father was accidentally led to the discovery that the fall of this meteorite was not vertical, but at an angle. The son writes as follows: "Largely by accident, my father observed one day that by firing a rifle into mud he could make an excellent replica of the Crater, and, moreover, that the rifle need not be fired vertically downward, but might be held even less than 45 degrees from the horizontal. Naturally one would suppose that a shot at such an angle

would make an elongated hole. But it will not. The hole will be just as round as though the shot had come straight down, although the projectile will lodge under one edge of the hole instead of in the center. A charge of shot fired from a shotgun at close range will produce the same effect." This observation led the elder Mr. Barringer to make a closer examination of the crater, the results of which indicated with great certainty that the mass had come from the north at a comparatively low angle.

Thereupon a drill-hole some 1400 feet deep was sunk on the south rim. Beginning at a depth of 1000 feet, a series of hard bodies carrying nickel, and clearly meteoric in origin, were struck. Of this boring, Mr. Barringer reported, "Eventually this hole (the last boring sunk through the south rim, it having been determined that the mass approached from the north at an angle of approximately 45°) encountered what is beyond doubt the upper part of the buried cluster of iron meteorites, finding it exactly in the predicted position." It is significant that geophysical investigations, both magnetic and electrical, as well as the geological evidence, all pointed to a large mass of meteoric iron under the southern rim; and two recent drill-holes in the southwestern part of the bowl about 1000 feet from the previous drill-hole on the rim, have also encountered numerous meteorites.

Volatilization?

It has been suggested that the energy of onward motion, when the meteoric body was suddenly stopped, would have been transformed into sufficient heat to vaporize all or part of the main body. Mr. Barringer believed, however, that due largely to being checked by the air, the meteoric body struck at too low a velocity to have been vaporized. The absence of stains, such as would be caused by the vapor which would have been formed by volatilization of the iron, he believed, strongly supported this view.

Dr. F. R. Moulton, formerly Professor of Astronomy in the University of Chicago, co-author of the Planetesimal Hypothesis, and leading student of celestial mechanics, arrived at the following conclusions:

"My interpretation of the probable event is roughly as follows: The dense part of the swarm was something like 2,000 feet in diameter and its mass was from 100,000 to 500,000 tons. It crashed into the rock to a depth of something like 800 to 1000 feet, carrying with it a large mass of greatly condensed (and consequently heated) air, which was further condensed on penetrating the rock. Ejected rock was thrown out not only by the condensed air and the steam generated, but also by volatilization of a considerable amount of the meteor and rock materials with which it came in contact."

Explosion?

Dr. Moulton discusses the fate of meteors of various masses in his ASTRONOMY (1931), closing with the following sentences: "But a meteorite weighing thousands of tons would not be greatly retarded by the air and would strike the surface at a high velocity. At a speed of 20 kilometers per second the resistance of surface soil or rock, due to its inertia alone, would amount to 32×10^9 grams per square centimeter; at 14 kilometers per second the resistance would be about half as great. Either of these pressures would be sufficiently great to cause the material of the meteorite to flow as though it were a gas. The energy given up in a tenth of a second would be sufficient to vaporize both the meteorite and the material it encountered—there would be in effect a violent explosion that would produce a circular crater, regardless of the direction of impact, which alone would remain as evidence of the event." The recent studies of Professor C. C. Wylie, of the University of Iowa, on the explosive effects of high-speed bullets upon striking a target evidently support the conclusions of Dr. Moulton. The stubborn reply to these theoretical conclusions, however, is the fact that thousands of meteorites of the original mass, several of which are mentioned on pages 4 and 5, *did remain* about the crater.

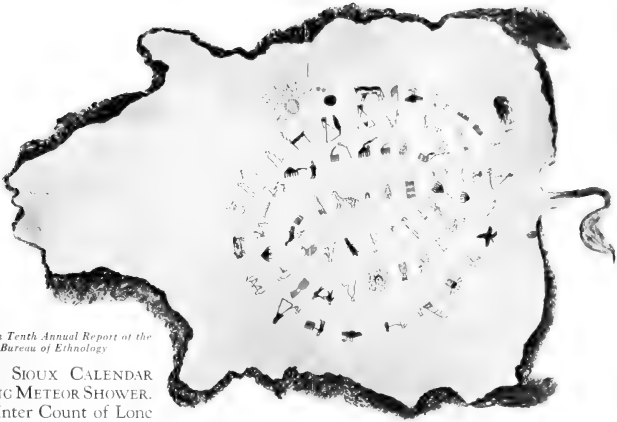
An inevitable question arises: What is the age of Meteor Crater? It is certainly young, geologically speaking. The sharp angles of the boulders and smaller fragments in the rim and talus indicate that. A Juniper tree growing on

Photograph by W. T. Gordon

Above: THE HOBA METEORITE. The largest known meteorite, located near Grootfontein, S. W. Africa, estimated to weigh from 50 to 70 tons. The second person from the left is Dr. L. J. Spencer, who has charge of the meteorites in the British Museum of Natural History.

Below: THE AHNIGHITO METEORITE. The Ahnighito, weighing 36½ tons, the largest meteorite in any museum, brought from Greenland in 1897 by Peary. Three other large iron meteorites, pretty surely of the same fall as the Ahnighito, were found nearby. Pieces of one of these had been laboriously hammered off by the Eskimos for knives. Clyde Fisher in foreground.

Photograph by Thane Bierwert, American Museum of Natural History

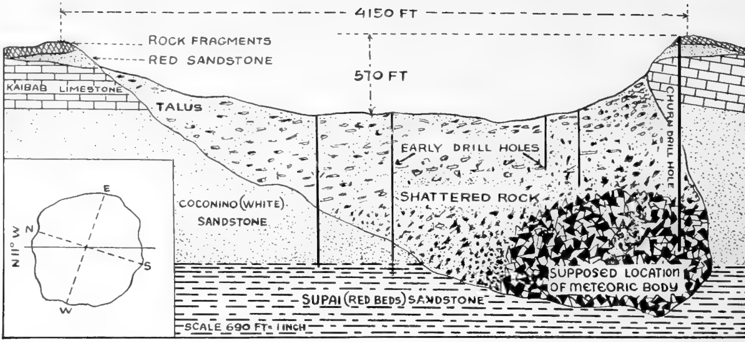


From Tenth Annual Report of the Bureau of Ethnology

Above: SIOUX CALENDAR SHOWING METEOR SHOWER. The Winter Count of Lone Dog, a Sioux warrior, showing the Leonid meteor shower of November, 1833,—when "the stars fell", as the Indians all agreed. The record is in the middle of second coil of the spiral from the bottom. In the original, in the Smithsonian Institution, the crescent moon is black and the meteors are red. (See cut on page 2.)

Below: BOULDERS IN THE WALL OF METEOR CRATER. Portion of the wall of the crater showing some of the larger boulders left as a result of the impact.

Photograph by Clyde Fisher



Cross-Section of Meteor Crater

the south rim is said to put it back at least 700 years, because it had that number of annual rings. The presence of lapilli and volcanic ash found in the lake deposits in the bottom of the crater correlate it with the last volcanic eruptions in the nearby mountains of Arizona. These, together with other evidences of the lake deposits, etc. point to a probable age of 40,000 to 75,000 years,—a conclusion arrived at by Dr. Eliot Blackwelder, Professor of Geology in Stanford University, who has made careful studies on two visits to the crater.

Craters of the moon

A comparison of Meteor Crater with the craters on the moon has led some scientists to believe that the latter were also caused by impact. While it is probably true that the majority of astronomers accept the volcanic theory of the origin of the moon's craters, there is much evidence in favor of the impact theory.

The difference in opinion among scientists can well be illustrated by the fact that the authors of the Planetesimal Hypothesis of the origin of the Solar System disagree. Professor T. C. Chamberlin was definitely opposed to the impact theory for the origin of the lunar craters, while Professor F. R. Moulton says that these craters may have been caused by the impact of planetesimals.

Some of the difficulties with the volcanic theory are as follows: volcanic craters on the earth are far less numerous than the craters on the moon, and yet the former belong to several types, while nearly all of those on the moon show great similarity, none on the earth being like the typical craters on the moon.

There are 30,000 craters on this side of the moon, and yet not a single lava-flow can be seen. There are no fissures on the moon from which lava has flowed.

As pointed out by Mr. D. M. Barringer, in his thorough-going work on this subject, there is not a single conical mountain peak on the moon which is similar to Fuji, Aetna, Vesuvius, Orizaba and other volcanoes of this type, made by the effusion of lava from a central vent and the building up of the mountain mass higher and higher as it flows down the sides.

Volcanic craters on the earth do not have central conical hills like those in so many of the lunar craters.

Finally the fact that the moon is not large enough ever to have held an atmosphere indicates that it could never have had enough water or oxygen to cause either the types of volcanic craters found on the earth or the far more abundant craters on the moon. Scientists who have studied volcanism hardly need to assure us, as they unanimously do, that there can be no volcanic phenomena in the absence of water and oxygen.

On the other hand, the impact theory, set forth by Richard A. Proctor in his book entitled "The Moon," has other facts in its favor.

The floors of the craters on the moon, as Mr. Barringer has stated, are usually far below the surrounding surface, as is true in Meteor

Crater in Arizona, whereas the floor of a terrestrial volcanic crater is usually above the original surface surrounding the volcano.

The only explanation that has come to the writer's knowledge for the formation of the rift through the lunar Alps is that it may have been caused by a huge meteorite or planetesimal which struck the moon tangentially.

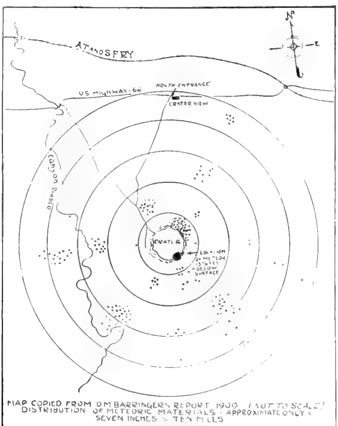
The central peaks

The central conical hills furnish strong evidence of the impact theory of the origin of the craters on the moon, as a study of splashes has shown. This is made clear by high-speed motion pictures of drops of liquids or, of small solid bodies, falling into liquids at rest. It is also shown by miniature craters produced by shooting bullets, or charges of shot from a shotgun at close range, into mud or other plastic media. At first, the circular shape of the craters on the moon did not seem to fit in with this theory, but experiment has shown that the craters would be circular even when the projectile arrives at a rather low angle.

The impact theory would explain the light-colored streaks which radiate from the craters Copernicus, Tycho, and others, in that they are probably made of rock-flour produced in exactly the same way as that at Meteor Crater in Arizona, and splashed out at the time of the impact. The great length of these streaks on the moon, and also the large size of the lunar craters are probably correlated with the small surface gravity on the moon, which is about one-sixth that on the earth, and with the absence of atmosphere on the moon.

The fact that there are so few impact craters on the earth as compared with those on the moon,—assuming that those on the moon were caused by impact,—is probably due to erosion. Water erosion, wind erosion, freezing and thawing, etc., have been active on the earth for millions of years, while on the moon, since there is no water and no air, there has been no erosion, except that very slight effect caused by the impact of meteors in the absence of the cushion of air, as pointed out in his book entitled "Meteors" (p. 254), by Dr. Charles P. Olivier, Professor of Astronomy in the University of Pennsylvania and President of the American Meteor Society.

Until recently it was believed that Meteor



MAP SHOWING DISTRIBUTION OF METEORIC MATERIALS AROUND METEOR CRATER

Crater was the only one of its kind on the face of the earth, while there are 30,000 on the side of the moon turned toward the earth. But more and more are being identified on the earth. The meteorite craters so far studied are distributed as follows: one near Winslow, Arizona; one near Odessa, Texas, identified as a meteor crater by Mr. Daniel Moreau Barringer, Jr.: one near Haviland, Kiowa County, Kansas, identified as a meteor crater by Dr. H. H. Nininger; a group of some thirteen near Henbury in Central Australia; a very small crater which contained the Huckitta Meteorite in Central Australia; a group of seven craters on the Baltic island of Saaremaa (Oesel) belonging to Estonia, which the writer had the opportunity of visiting in the summer of 1936, identified as meteor craters by Mr. I. Reinvald in 1927; the Wabar craters in Arabia; the Siberian craters; a doubtful one at Ashanti, in West Africa; a very doubtful group near the coast of South Carolina; a supposed crater in Persian Baluchistan; and the Campo del Cielo craters in Argentina. No meteorites have been found at the Siberian craters, and none at the South Carolinian craters.

Certainly no other meteor crater has been so thoroughly studied as the one in Arizona, and judging from a comparison of these studies with the published descriptions of meteor craters in other parts of the world, certainly none is more interesting or impressive.

Our poet-astronomer, William Tyler Olcott, has paid tribute to this gigantic bowl in the following lines, titled "Meteor Crater, Arizona."

You were a black moth winging through the night,
A bit of cosmos shorn from molten matter,
One of a swarm with beating wings that batter
The source and all reflections of the light.

You were the silent echo of a voice,
A slave to might beneath the lashes bending,
And then you plunged to death in flames descending,
In answer to predestinated choice.

You now within a mausoleum lie,
And men gaze on your sepulchre in wonder,
Far down beneath the earth you rent asunder,
You rest secure and dream of star and sky.

Issued under the direction of the Committee on Popular Publications.

Roy W. Miner, *Chairman*

SOUTH AFRICAN ROCK PICTURES

by N. C. NELSON

Science Guide #93

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Curator of Prehistoric Archaeology, American Museum of Natural History

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SOUTH AFRICAN ROCK PICTURES—Striking artistic achievements of prehistoric man, which tell a story of the dim past and inspire modern artists with their technique

By N. C. NELSON

Curator of Prehistoric Archaeology, American Museum of Natural History

PRIMITIVE art, both ancient and modern, has long received special attention from the anthropologists and, judging by museum experience, is gradually winning its way also in popular esteem. The reason perhaps is not far to seek. Art has a wider and more instant appeal than science; for while we may appreciate beauty at first glance, time and study are required to reach an understanding of the technicalities involved even in art itself. The reference here is not to music, singing, dancing or story-telling, but to decorative and pictorial art; that is, to permanent objective representations such as in one form or another are profusely exhibited in every anthropological museum.

In the case of the American Museum of Natural History, still adhering to the scientific mode of mass presentation, the artistic features of our various regional exhibits are studied and copied annually by hundreds of art students, with the result that many of the sometimes ancient design elements have long since been readapted to modern usage. A few museums have actually sought to meet this popular demand by rearranging their exhibits so as to stress the artistic features.

There are two special reasons for commenting on primitive pictorial art at this time. One is that the people of New York City were privileged not long ago to view the reproductions of a large series of native African rock pictures brought by Professor Leon Frobenius from Frankfort-on-theMain, Germany, and exhibited at the Museum of Modern Art. Professor Frobenius has given a lifetime of study to this type of art, has conducted no less than twelve expeditions to widely separated regions of the African continent, has copied thousands of pictures, and has published extensively on the subject. The other reason is that the American Museum has itself recently acquired the series of carefully made copies of similar rock paintings accompanying this article. These were selected from a large series offered for sale by Mr. M. K. McGuffie, a South African artist who has also devoted much time to the study and whose work has been duly complimented by Professor Frobenius himself.

The McGuffie reproductions herewith illustrated all come from one of the richest rock-painting localities in the world, namely, the eastern portion of Cape Province in extreme South Africa, as shown on the map on page 4. Within an area, measuring roughly seventy miles from north to south and one hundred and fifty miles from east to west, over one hundred localities are indicated in which

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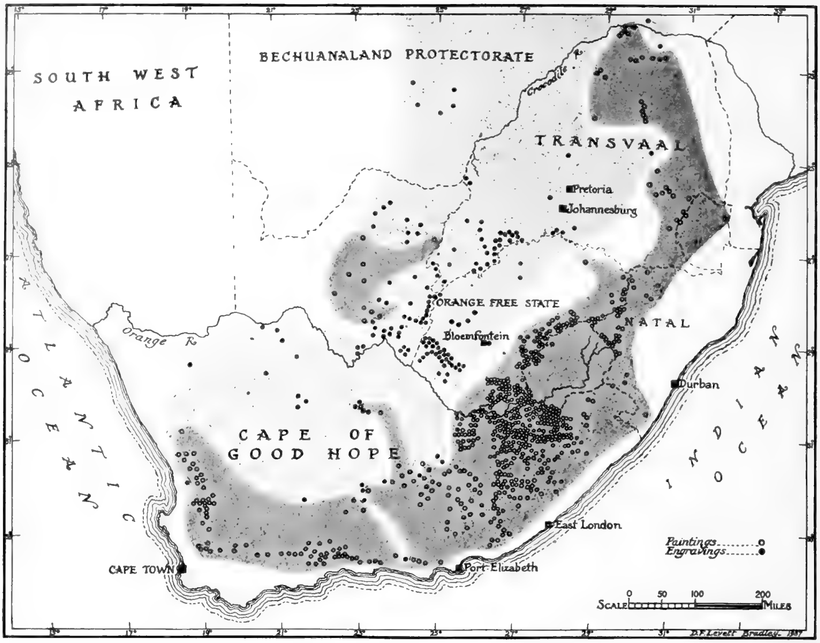
NELS C. NELSON, one of America's most eminent archaeologists, was born and raised on a farm in Denmark. Recalling his early education as a Minnesota farm boy (he emigrated to this country in 1892), Mr. Nelson tells that at the age of seventeen he was spelling C-A-T among classmates that came only as high as his knee. He first became interested in archaeology while attending the Omaha Exposition of 1898 where a graphic history of Man's tools was on display. Mr. Nelson was both a student and a teacher of Anthropology at the University of California and it was in the San Francisco Bay region that he conducted his first major investigations which were later expanded to include the American Southwest. Since that time other sections of this continent together with western Europe and parts of Asia have been explored by Mr. Nelson. As Curator of Prehistoric Archaeology at the American Museum he was in charge of the archaeological branch of Roy Chapman Andrews' Asiatic Expeditions. Mr. Nelson has held official positions in several scientific societies and is an active member of many others. Among the varied archaeological phenomena that have come within the broad scope of his work, during his association with the museum are the prehistoric cave drawings of ancient man.



Rock Paintings and Engravings

Note the abundant sites where this type of primitive art has been found in South Africa. The darker shading indicates the distribution of paintings, the lighter that of engravings. Though the two modes of pictorial representation were presumably the work of the ancestors of the Bushmen, their distribution does not overlap to any marked extent. The drawings reproduced in this article all come from an area approximately 70 by 150 miles (26-29 degrees east and 31-32 degrees south), in which over one hundred localities are indicated.

(After the Bureau of Archaeology 1936 map, Department of the Interior, Union of South Africa)

more or less extensive groups of rock paintings have been discovered. As seen on the map, however, this area contains only a small fraction of the known art centers in South Africa. Except near the coast, where rock paintings do not occur probably owing to the absence of suitable rock surfaces, they range over a zone in places two hundred miles wide, which parallels the coast for more than fifteen hundred miles. Farther inland, behind this curving zone of rock paintings, there is an equally extensive explored area characterized chiefly by petroglyphs or rock engravings. Curiously enough, although the two modes of pictorial representation were presumably the work of the same people, namely, the Bushmen, their geographical distribution does not appear to overlap to any marked extent.

World distribution of mural art

In passing, it must be made clear that prehistoric rock pictures, both painted and engraved, are not confined to South Africa. Their distribution is world wide. They occur, for example, also in Southwest Africa, in East Africa near Lake Tanganyika, and in various parts of all North Africa, including what is now the Sahara desert. In Europe, relatively re-

cent, i.e., Neolithic, Bronze and Iron Age inscriptions, more or less pictorial, are found in Sweden, in the British Isles, in Belgium, in northwestern France, in northwestern Spain and in Italy. A small series of more ancient rock pictures occur in Russia and Norway; but, as far as is known, the most ancient and in some respects the most noteworthy examples of prehistoric mural art are confined to the caves and rockshelters of southern France, as well as parts of northern and eastern Spain. Asia has furnished at least a few examples from the Near East and from India, and the writer has himself observed a considerable number of rock engravings in Outer Mongolia. Even far-away Australia has supplied some striking examples of both rock engravings and cave paintings. Lastly, needless to say, rock pictures of all types are also an outstanding archaeological feature of both North and South America, being especially numerous in our own Southwest, where conditions for their production and preservation have been particularly favorable.

Mural art styles

Turning now to the Old World, specifically to Europe and Africa, and taking Frobenius for our principal guide, we learn that this vast region is characterized by two distinct art styles. One of these styles he calls Franco-Cantabrian and the other Levantine or Eastern.

The first and probably the older style, best known from southern France and adjacent parts of northern Spain, but found also in various regions of Africa, as, for example, the Atlas mountains, southern Tripoli, and far-away South Africa, is characterized by isolated or individual representations of mammals, birds, fishes, insects, and human beings. These pictures are mostly polychromes, done sometimes to a scale approaching natural size and often in the manner of faithfully rendered natural poses.

The second or Levantine style, typical of eastern and southeastern Spain, southern Tripoli, the Libyan desert and South Africa, is unique in that the pictures are usually small scale monochromes and represent real compositions or groups, illustrating for the most part hunting or dancing scenes. These pictures are executed in a slightly conventional manner, as may be seen in some of the accompanying illustrations.

The first or Franco-Cantabrian style Professor Frobenius calls "portrait pictures," and the second or Levantine style "action pictures." As the reader must have noticed, the two styles occur together in at least two places, namely, southern Tripoli and South Africa; but in the opinion of several students the first or Franco-Cantabrian style is the older. Apparently, therefore, the two art styles, imitative and interpretive, were practiced by different peoples, through whose various migrations the separate traditions were carried in several directions from the points of origin, probably the lands bordering the western Mediterranean. Professor Frobenius himself appears to maintain the view that both styles originated in southwestern Europe and from there by degrees spread, for example, to South Africa, the Franco-Cantabrian style being the first to arrive. He also regards the African pictures as ranging in time from about 10,000 B. C. down to the present day.

The beginnings of art

As cultural documents these cave wall pictures aside from their esthetic value, constitute one important phase of the middle portion of a long, many-sided story—the story of the devolpment of human civilization. Briefly told for southwestern Europe, where alone it has been well worked out, the art side of this story—giving us the true setting of our South African pictures—is about as follows. Artistic expression, viewed historically and in the large, began in Upper Paleolithic times, some fifteen or twenty thousand years ago, as a crude imitative or realistic endeavor, which slowly improved and then by degrees underwent a process of stylization or schemetization, amounting throughout the succeeding Neolithic Age to almost complete degeneration, at least as far as copying nature was concerned.

At first sight this transformation strikes one as perhaps the natural and therefore the universal law of art development. That is, it seems a clear case of the normal conversion of naturalism into conventionalism or, in more specific terms, pure art giving rise to applied art. Viewed in this light one is tempted to regard it as an illustration of pictorial art, originated and developed by men, giving way to decorative art, practiced mostly by women. One might also argue with some show of reason that the so-called degeneration was more apparent than real because due to inherent necessity. The explanation is this. When the free-hand portrait art, executed on large cave-wall spaces by the early nomadic hunters, was applied by the later sedentary agriculturists to the small surfaces of basketry and textiles, under the limiting conditions imposed by weaving, the naturally flowing outlines of the animals depicted had to be sacrificed for results that were angular and more or less geometric.

But, unfortunately, while both of these suggestions must be given some weight, the fact remains that women were not the original creators of stylized symbols and geometric patterns, for these appear at an early date as the work of men in the caves alongside the pictorial representations, where they were not the result of necessity. Also, though it is true that some of the geometric conventionalizations, once achieved on textiles, were reproduced on the cave walls and later copied on pottery, pottery surfaces, though small, lent themselves as easily to pictorial representations as did the cave walls. Moreover, elsewhere in the world, as for example in our own Southwest, animal pictures of admittedly inferior character were executed on both cliff walls and pottery throughout most of the Neolithic Age. In Europe, however, this was not the case in any true sense, though here mural art was eventually revived in degenerated form during the Bronze and Iron ages and in the natural course of artistic development improved for distinctly decorative purposes throughout historic times.

A survival

We must conclude, therefore, that pictorial art of the strictly Paleolithic style disappeared from southwestern Europe as a natural result of the decadence of the hunting cultures during Mesolithic times, i.e., actually some time before the dawn of the true Neolithic Age, or about ten thousand years ago. In northern Europe the tradition lingered on for a considerable time, while in Africa it flourished without marked change almost to the present day.

Having indicated the historical position of Old World pictorial art, let us next take a swift look at its contents. The various products of the whole endeavor fall into two grand divisions: stationary art and portable art. By stationary art is meant simply human and animal representations painted, etched or sculptured on cave or cliff walls and therefore permanently fixed. Belonging to this group are also a few examples of clay modeling, similarly immovable and which therefore, like the mural creations, were in a sense public property for everyone to see. Portable art, on the other hand, comprises small objects of all sorts carved in or engraved upon pieces of stone, bone, ivory, antler, shell or wood and which could have been moved about and owned as personal possessions. Both of these art manifestations, fixed and movable, as well as beads, pendants and other forms of bodily adornment, make their first appearance in Europe with the coming of the so-called Cromagnon man. But where precisely the Cromagnon man came from is still a mystery. Possibly it was North Africa; though, if so, it is strange that he appears to have left there next to no remains of portable art objects. Only stationary art is at all well represented here and the same is true, as far as present knowledge goes, for all the rest of prehistoric Africa.

Characteristics of South African pictures

As would be expected, all the earliest artistic efforts were crude. In Europe mural representations of animals, though the subjects must have been very familiar to the artists, began as amateurish profile outline drawings, either deeply incised or painted in a single color—red, brown or black. Depth or perspective was lacking, the animal depicted showing usually only one fore leg and one hind leg. In time this was remedied, with distinctly lifelike results; and in addition full-bodied representations appear, the enclosed contours being stippled, scraped or painted all over, the last process yielding monochrome silhouettes. Finally, the painted monochomes developed into variously shaded polychromes and the etchings or engravings reached a fair degree of excellence as high relief sculptures. This, however, was the course of progess in Europe only, and with that in mind let us turn finally to a brief consideration of corresponding art as practiced in South Africa.

In Africa the earliest examples of mural art are not so easily identified as in Europe. Perhaps the sequence is not complete because the pictures here were executed not in deep sheltering caves but in open rockshelters and the oldest may long since have weathered away. Also it is possible that the art having been introduced, at least in the south, in developed form, the preliminary stage never existed. But, as may be seen in the accompanying illustrations, pecked (sometimes incised) outline and full-bodied pictures are present, as are also both monochrome and polychrome paintings. The mineral colors employed were varying shades of red and brown, also white, black, and on rare occasions yellow and blue. The colors used do not as a rule correspond to the colors of the animals depicted but are arbitrary; and in the case of polychromes the different hues employed for different body portions meet abruptly without intermediate shadings. Some students are of the opinion that the prevailing colors varied from time to time and that in this way some four or five sequential stages may be distinguished. Thus the first or oldest pictures are thought to be monochromes in reds and yellows, the second series are in deep reds and browns, the third in light red, the fourth polychromes of vari-

ous hues, and the fifth and last simple blacks and whites. Other investigators present the order of succession in more general terms: monochromes, polychromes, and a final series showing a marked decline.

Concerning the essential characteristics of the art as art, i.e., as to drawing, perspective, composition, rhythm and so on, little can be said here. Technique and style are there, but the illustrations must be left to speak for themselves. As may be seen, the outstanding features are realistic. Conventional symbols, idols, and fabulous creatures are either rare or absent. In this respect the art, although certainly affecting a unique, almost modernistic flair, comes much closer to the natural model than does the art of the African negro. Here is depicted, as a rule, only the realities of daily experience: animals running, grazing, falling or lying down; also men hunting or dancing, with and without disguise; and occasionally men in council and in procession. The pictures must, in short, be attributed to a people of essentially the same mentality or cultural status as the Paleolithic hunters of Europe. And these people are by common consent supposed to be the slowly vanishing Bushmen.

Age of the South African pictures

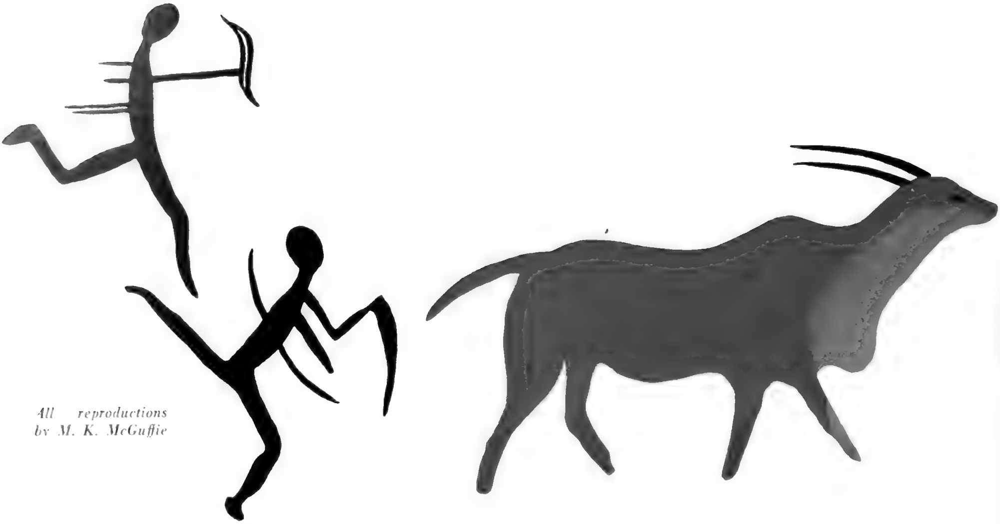
Everyone will ask: How old are these South African art treasures? The answer is, no one knows precisely. It is generally agreed, however, that the most ancient may be several thousand years old and it is definitely known that the latest were made by the Bushmen as recently as seventy-five years ago. But the Bushmen were not the first inhabitants of South Africa and so it is possible that some of the oldest rock pictures may antedate their coming and are to be credited to another people. In either case it is reasonably certain that the South African pictures were made by a people who, as in Upper Paleolithic times in Europe, made specialized implements adapted from flint flakes and not, as in earlier days, crude generalized implements improvised from cores.

Significance of rock pictures

In conclusion, a few remarks must be ventured about the meaning and purpose of the rock pictures in South Africa and elsewhere. As the reader must already suspect, the question, long under dispute, remains largely unanswered. Surviving primitive peoples seldom have any explanations to offer and the opinions of students differ widely. Some have held that most of the inscriptions were the work of idle hours and as such have no more profound meaning than the improvisations made by modern boys and girls on the fence and sidewalk; that, in short, they merely satisfied an innate craving for expression. Others claim that we have something more than that, in fact purposeful art for art's sake. Still others—and these are in the majority—have invested the pictures with a religious or magical purpose. Thus they claim, and with good reason that the animal pictures, for instance, were part of an incantation process carried out to ensure success in hunting the real animals. Such ceremonies have actually been witnessed in Africa, where natives before going on a hunt first drew on the ground a picture of the animal wanted and then while mumbling incantations over it shot arrows into the picture—a form of well-known sympathetic magic. Some of the compositions actually depict hunting and dancing scenes, both of which may well have had magical purposes. Others may have illustrated mythological conceptions or may have recorded important events in tribal history.

We can follow the fascinating subject no farther. Probably all the above suggestions have to be taken into account. The peoples who made the ancient pictures were not so very different from ourselves and we may safely assume that their artistic achievements served much the same purposes as our own. Art is an essential function of life, explain it how we may.

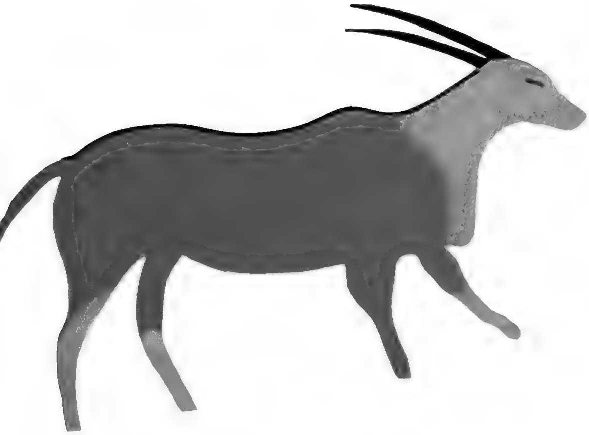
THE DANCE, which next to hunting was the most popular subject of the prehistoric artist



All reproductions by M. K. McGuffie

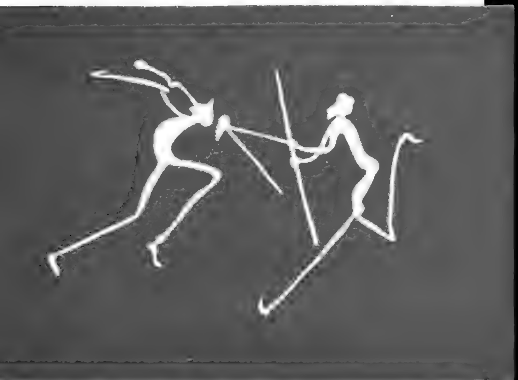
(Above) The chase: two elands pursued by a pair of hunters. The streaks at rear of the upper figure represent arrows; in front of him is a badly drawn bow. Compare the tail of the central eland with the one at right: the lower human figure is believed to have just chopped off the end of it with the weapon in his hand, probably a stone axe. This hunter carries his bow slung across his body

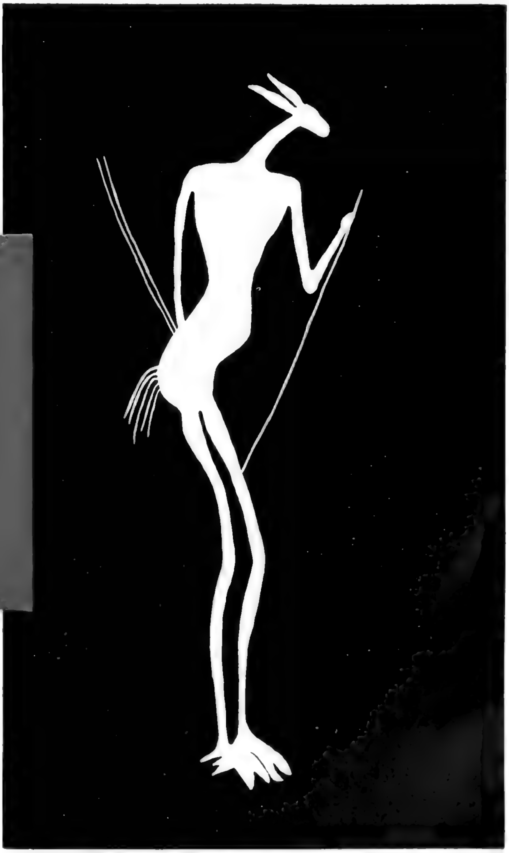
(Above) The prank: a boy with two puff-adders scaring his companions. Notice how the primitive artist expresses flight and abject terror with the greatest economy of detail—a technique copied by many modern artists. The rock gallery where this picture was found is near a river infested with snakes, which form quite an important part of the modern Bushman's food. The latest of these South African art treasures were made as recently as 75 years ago by the Bushmen; the most ancient may be several thousand years old and denote a mentality and cultural status similar to that of the Paleolithic hunters of Europe



Two broad types are distinguished in the primitive rock pictures widely distributed over Africa and Europe: (1) "portrait pictures" representing single animals or human beings, mostly in varied colors and relatively large in scale (Franco-Cantabrian type); and (2) "action pictures" of groups illustrating for the most part hunting and dancing scenes, usually in monochrome and small in scale (Levantine or Eastern type). The South African pictures are definitely "action pictures" (although not always in monochrome), and are in the tradition of the Paleolithic style which disappeared from southwestern Europe about 10,000 years ago. They present an almost modernistic flair in their freedom, realism and absence of conventionalized symbols.

(*Below*) THE FIGHT: a battle between two Mantis-Men, or Kaggan. Symbolizing the courage and combative nature of the insect known as the praying mantis, the Mantis-Man is regarded by the Bushmen as a spirit of mischief and is a favorite subject of the rock painters of old. In this grotesque picture, conveying a sense of fierce action, the weapons so vigorously wielded seem to be a wooden club, hook, spear and stone-headed axe.

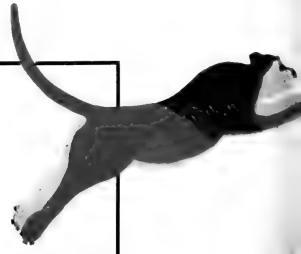


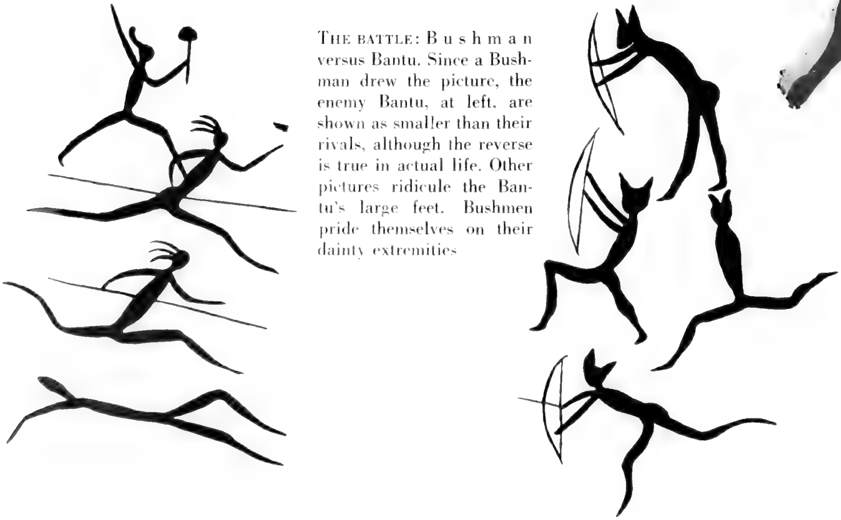


(*Right*) THE MANTIS-MAN: a mythical creature apparently important in the spiritual philosophy of the ancient artists. As in this example it is frequently presented as a hunter wearing a buck's head-mask and always with long thin legs. Today the mantis is referred to as the "Hottentot god," and when one alights on a Bushman he will sit perfectly still until it flies away.

(*Above*) THE RAIN-MAKERS: an ancient depiction of a ceremony for bringing rain. Legend has it that the "Rain Bull" and the "She Rain" (mythical animals) were led to an appointed place by the witch doctor of a Bushman clan, and there slain so that the rain might descend and produce the plant-life on which the Bushmen depended for food. This painting shows evidence of being extremely old

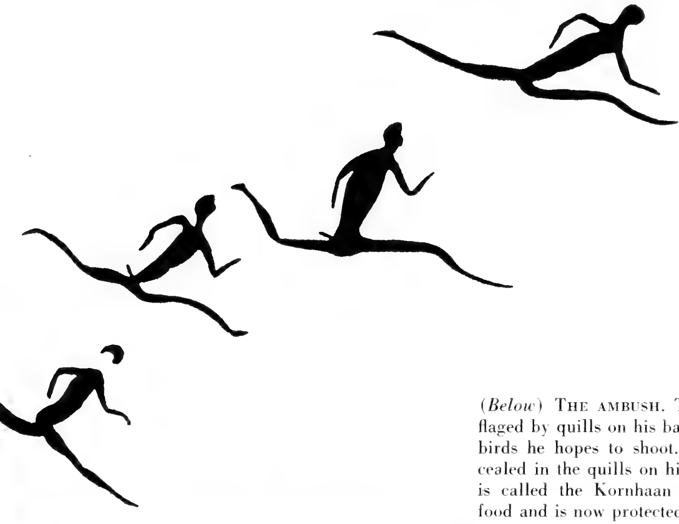
(*Below at right*) THE CHARGE: a black-maned lion pursuing a group of fleeing men. In the original picture, a veil-like film of black has been traced over the yellow ochre of the lion's shoulders, apparently intentionally as it cannot be accounted for by rock exudation. This latter phenomenon is effacing many of the pictures in this particular gallery, and total disappearance is only a matter of time





THE BATTLE: Bushman versus Bantu. Since a Bushman drew the picture, the enemy Bantu, at left, are shown as smaller than their rivals, although the reverse is true in actual life. Other pictures ridicule the Bantu's large feet. Bushmen pride themselves on their dainty extremities

(*Right*) THE RITUAL: a picture probably intended to represent a nocturnal ceremony as indicated by the artists having chosen a poor surface of dark rock for it instead of better mural surfaces above and below. The crosses at top are stars, the pear-shaped objects at right are flames or sparks of a fire rising from horizontal faggots. Ostrich plumes and animal heads appear to be part of the ornamentation of the weird figures



(*Below*) THE AMBUSH. This picture shows a hunter, camouflaged by quills on his back and hands, stealing up on the two birds he hopes to shoot. It is possible that arrows are concealed in the quills on his hands. This species of ground bird is called the Kornhaan (pronounced Koraan), is excellent food and is now protected by law

(*Above*) THE WILD-PIG HUNT: a scene which like many others is believed to be part of an incantation process to insure success in hunting. The dogs at upper left are apparently aiding in the chase. The sling-like weapon is judged to consist of three perforated stones on separate strands

(*Below*) AN ELAND pecked in rock: an example of the primitive rock engravings, which extend over a wide area in South Africa. Although geographically they do not overlap the paintings, both are believed to be the work of the same people, the ancestors of the present Bushmen

Photo A.M.N.H. and Charles H. Coles

Pocket Guide to the Exhibits

in

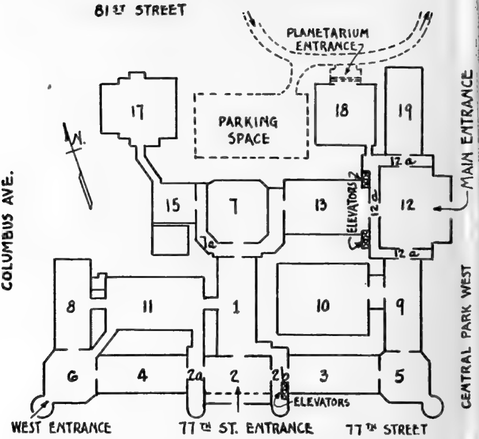
The American Museum of Natural History

Guide Leaflet Series

No. 94

Revised

Central Park West at 79th Street,
New York, N. Y.
1939



FLOOR PLAN

THE AMERICAN MUSEUM OF NATURAL HISTORY

THE American Museum of Natural History occupies most of the space between Central Park West and Columbus Avenue and 77th and 81st Streets. The main entrances are on Central Park West, through the Roosevelt Memorial, at three levels, street, vehicle (driveway beneath the steps) and subway. There is also an entrance on West 77th Street (foot and vehicle, center of block), and one on Columbus Avenue, near 77th Street (foot).

The Planetarium may be entered from West 81st Street (vehicle and foot) and through the Museum. Cars may be parked within the Museum square (enter from 81st Street) and at the curb on the streets surrounding the Museum square.

There are 13 acres of Exhibition Halls in the American Museum, none being above the fourth floor. This leaflet presents an alphabetical list of the exhibits and a statement of the floor and hall in which they may be found. It is designed only to acquaint the visitor with the nature of the exhibits as a whole and to guide him to those he wishes to see. For example, assuming the visitor wishes to see an exhibit of the Birds of the World, he refers to **Birds** and, under this heading, finds that it is placed on floor **II**, hall **1**. Having reached floor **II** (there are elevators in the Roosevelt Memorial and near the 77th Street entrance) he refers to the diagram on page 2 of this leaflet and finds the location of hall **1**.

General and special guides to the exhibits themselves may be purchased at the Book Shop (entrance Roosevelt Memorial, floor **II**). Specific information may be secured at the entrances and from museum attendants throughout the building.

All halls are open from 10 — 5 on week days and from 1 — 5 on Sundays, Independence Day, Thanksgiving, Christmas and New Year's Day. There is no admission charge except for the Planetarium.

Floors in Roman figures, halls in Arabic.

Animal Behavior, Hall of,

Exhibits showing the reaction of animals. The world as it appears to lower animals. **Basement, 12.**

Anthropology.

(See under: African Ethnology, Archaeology, Asiatic Anthropology, Eskimos, Indians, Natives, Natural History of Man, Pacific Islands, Philippine Hall).

Archaeology, Central American, Mayan and Mexican.

Models of temples, calendar stone, sacrifice stone, sculpture, manuscripts. **II, 4.**

Archaeology, Old World.

Cave art, the Stone Age, Bronze Age, Iron Age, etc. **II, 6.**

Archaeology, West Indian. **II, 8.**

Archaeology, United States and Canada. **II, 6.**

Archaeology. See also Indians, Southwest; Indians, Woodland; Age of Man.

Asiatic Anthropology.

Siberia: models, fur garments, ivory carving, etc. China and Tibet: bronzes, jades and religious objects (see also Drummond Hall, **IV, 6**). **III, 6.**

Asiatic Hall.

(Regional Fossil Vertebrates). Mongolian dinosaurs. Dinosaur eggs. Mongolian Tertiary and Cretaceous mammals and reptiles. Dean Memorial Collection of fossil fishes (see Guide Leaflet No. 81). **IV, 5.**

Asiatic (North) Mammals (see Mammals). **II, 5.**

Asiatic (South) Mammals (see Vernay-Faunthorpe Hall). **II, 9.**

Asiatic Natives (see Asiatic Anthropology). **III, 6.**

Astronomy.

Hall of the Sun: with mosaic replica of Aztec calendar stone, mural of 12 zodiacal constellations, and 40-ft. animated model of solar system. Collection of about 3,500 meteorites, representing some 550 falls. Illuminated transparent photographs of celestial objects. Telescopes, etc. Mural depicting astronomical myths

Floors in Roman figures, halls in Arabic.

of American Indians. Old and modern time-keepers, sun dials, hour-glasses, compasses, etc. Book Corner —astronomical publications. **I, 18.**
Astronomical paintings: Total eclipses of sun, solar prominences, lunar landscape, northern lights. Transparent photographs of heavenly bodies. Astronomical models. Old astronomical books and historical telescopes. Armillary spheres, celestial spheres. **II, 18.**
Telescope-making workshop, for use of Amateur Astronomers. **Basement, 18.**
See also Hayden Planetarium.

Auditorium. **I, 7.**

Auduboniana. **IV, 12a.**

Aztecs (see Archaeology, Central American). **II, 4.**

Bimini Group (see Fishes).

Biology of Birds, Hall of. **I, 19.**

Biology of Mammals, Hall of,
Mammals arranged in evolutionary series; special exhibits to illustrate adaptation, specialization, occurrence of albinism and melanism, and other biological principles. Skeleton of Jumbo. **III, 3.**

Biology of Man (see Man, Nat. Hist. of). **III, 4.**

Bird Art, Gallery of. **IV, 19.**

Birds.
(See Guide Leaflet No. 90. This alphabetical guide to exhibits and many species may be secured from the vending machine, floor **II,** hall **1.** A framed copy is placed above the vending machine).
Accessory and Subject Groups. Separate cases illustrating certain subjects and the nesting habits of single species are placed on the second floor halls one and two. Their exact location is given in the Alphabetical Guide. **II, 1; II, 2.**

Birds: Flying Bird Dome.
Illustrating notable birds of flight and flock-formation in the air. **II, 1.**

Birds, Hall of Biology of. **I, 19.**

Birds, Oceanic. **II, 19.**
(See Whitney Memorial Hall).

Floors in Roman figures, halls in Arabic.

Floors in Roman figures, halls in Arabic.

Geology, and Invertebrate Palaeontology, Hall of,
The preservation and significance of fossils. Pre-Cambrian rocks and ores. Fossil plants and fossil invertebrates, variously grouped by geologic periods and by classes. Collection of types and figured specimens. Topo-geologic and palaeographic models. Model of copper mine. Cave grottoes. Model of Panama Canal (see also Geology, **Corridor III, 7a**). **IV, 1.**

Geology—Corridor.
Geological relief models. Volcanoes, paintings and specimens. Ores, rocks, and building and memorial stones (see also Geology and Invertebrate Palaeontology **IV, 1**). **III, 7a.**

Giant Panda Group. **II, 5.**

Glass Flowers, Menken Collection of (see Hall of Forestry and Conservation). **I, 3.**

Gold Ornaments, Central America and Peru (see Archaeology). **II, 4; II, 8.**

Growth of Man (see Man, Nat. Hist. of). **III, 4.**

Guide Leaflets of Exhibits for sale in vending machines. **I, 4, 5, 10; III, 4; IV, 2, 4.** (see also Book Shop, **I, 2, 2b**).

Hayden Planetarium (see also Astronomy).
The performances of the Zeiss Projection Chamber on the second floor are the chief feature of the Hayden Planetarium. Here, in the 75-foot circular room, a composite magic lantern projects on the dome-shaped ceiling the beauty of the daytime and night-time sky, the ever-changing beauty of stars, planets, sun and moon. The subject changes monthly. Shows are scheduled as follows:

Weekdays, Saturdays, and Holidays—11:00 A. M., 1:00, 2:00, 3:00, 4:00, 5:00, 8:00 and 9:00 P. M.

Sundays—2:00, 3:00, 4:00, 5:00, 8:00 and 9:00 P. M.

General Admission—
Mornings and Afternoons — 25c.
Reserved Seat — 50c.
General Admission Evenings — 35c.
Reserved Seat — 60c.

Floors in Roman figures, halls in Arabic.

Exhibits—(occasionally changed). For fixed exhibits see Astronomy, **II, 18**; entrance from 81st St. and from **II, 12a; I, 12a.**

Horse, Evolution of (see Age of Mammals). **IV, 3.**

Horse under domestication, Evolution of,
Exhibits illustrating modification brought about through selection in adapting the horse to its various needs. Skeletons of some famous horses. **IV, 2a.**

Indians, Northwest Coast (U.S.).
Totem Pole makers. Tribes of Vancouver Island and Alaska. Large wood carvings, etc. **I, 1.**

Indians, Plains (U. S.).
The Buffalo-hunting tribes and the semi-agricultural villages of the Missouri. Tipi group and models. **I, 6.**

Indians, South America.
Peru, Bolivia, Chile, Brazil. **II, 8.**

Indians, Southwest (U. S.).
Navajo and Apache; two large habitat groups. California Indians; Pomo baskets; Pueblo Indians; modern villages in New Mexico and Arizona—Hopi, Zuñi, etc. Prehistoric collections from New Mexico and Arizona; Cliff-dwellers, ancient pottery, tree-ring data, and models of ruins. **I, 8.**

Indians, Woodland (U. S.).
The important tribes from the forested lands east of the Mississippi. Also some archaeological collections from New York and the Southern States. Large and small habitat groups. **I, 4.**

Insect Life, Hall of,
General exhibits; habitat groups; economically important insects (see also Public Health, **I, 15,** and Darwin Hall, **I, 5**); insects of a suburban yard; most beautiful butterflies and moths in each of the principal zoogeographic regions; live insects (temporary exhibits); anatomy, life-histories, and other biological features. Model of mole-cricket. Leaf-cutting ants. Stingless honey-bees. **III, 5.**

Insects.
Examples of typical insects of northeastern United States. Exhibit of water-color drawings of the eggs, caterpillars and pupae of butterflies and moths. (Southeast corner, inner railing) **III, 3.**

Floors in Roman figures, halls in Arabic.

Insects of New York.
The butterflies and some of the moths of New York State. (West end of south wall) **I, 12a.**

Insects, Fossil (see Geology). **IV, 1.**

Invertebrate Palaeontology (see Geology).

Invertebrates.
(See Darwin Hall, Corals, Pearl Diving Group, Shells, and Invertebrates of New York; see also Insects.) **I, 5, 10, 12a.**

Invertebrates, Fossil (see Geology). **IV, 1.**

Invertebrates of New York.
Representative species of the state. (South passageway) **I, 12a.**

Jade (see Drummond Hall). **IV, 6.**

Jade, Mayan and Mexican (see Archaeology). **II, 4.**

Jesup Collection of Trees of North America (see Trees). **I, 3.**

Lantern Slides, Sales and Service (see Department of Education). **III, 11.**

Library.
Reading room and reference library of natural history, anthropology, and travel. **V, 2a, 4.**

Lindbergh Exhibit.
Aeroplane "Tingmissartoq" and accessories. The plane used by Charles and Anne Lindbergh in their exploratory flight across the United States to the Orient and across the North and South Atlantic Oceans and Europe, 1930, 1931, and 1933. **I, 10.**

Living Reptiles, Habitat Groups of. **Basement, 12.**

Mammals (see also Biology of Mammals). **III, 3.**

Mammals, African (see Akeley Hall). **II, 13.**

Mammals, Fossil (see Age of Mammals, Asiatic Hall, Age of Man).

Mammals, Marine (see Ocean Life, Hall of). **I, 10.**

Mammals of New York.
Representative series of mammals of the state. **I, 12a.**

Manta (see Fishes).

Floors in Roman figures, halls in Arabic.

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Issued under the direction of
the Committee on Popular Publications.

ROY W. MINER, *Chairman.*

EARTH AND NEIGHBOR WORLDS

BY CLYDE FISHER

NEW YORK

EARTH AND NEIGHBOR WORLDS

By

CLYDE FISHER

Curator of Astronomy and Curator-in-Chief of
The Hayden Planetarium

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THE HAYDEN PLANETARIUM
CENTRAL PARK WEST AT 81st STREET
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1938

EARTH AND NEIGHBOR WORLDS

By CLYDE FISHER, Ph.D., LL.D.,

Curator of Astronomy and Curator-in-Chief of the Hayden Planetarium,
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New York City.

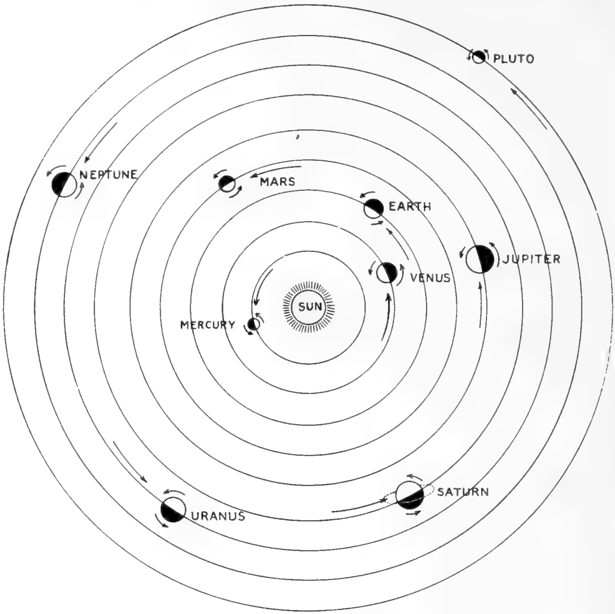
THE planets are members of the same family that includes the Earth. In fact, the Earth is just one of the planets. When a planet sets in the evening after the Sun, it is called an evening star; when it rises in the morning before the Sun it is known as a morning star. The planets, however, differ greatly from the stars. The planets are worlds, all of which revolve around our Sun, and they all go round the Sun in the same direction. Their paths lie so nearly in the same plane, that they occupy only a narrow belt in the heavens, called the zodiac.

While the planets, as the name indicates, wander about in the sky, they do not wander everywhere. No one has ever seen Venus in the Big Dipper, nor Mars in the Southern Cross, nor Jupiter in Cassiopeia. It is evident that the planets are under the control of the Sun. They are all comparatively cold, and shine only by reflected sunlight. On the other hand, the stars are all suns and, being very hot, shine by their own light. It is often said by way of distinction that stars twinkle and planets do not. While this distinction is in general true, yet the planets are apt to twinkle somewhat, especially when near the horizon, due to the increased disturbance of their light by refraction phenomena. The movement of the planets against the background of the stars is distinctive, although it takes a comparatively long time to determine it.

Before the time of Copernicus, it was generally believed that the Earth was the stationary center of the universe, and that the planets as well as the other heavenly bodies revolved around the Earth. It was observed that the planets moved most of the time eastward through the sky, but it was noticed that periodically they moved for a short time westward. This so-called retrograde motion was explained by Ptolemy, the great Alexandrian astronomer, by means of epicycles, that is, circles upon circles. To take Mars as an example, he believed that Mars moved around a small circle, the center of which moved around the Earth in a larger circle. Thus he was able to account for the backward or retrograde motion of a planet.

Now, we are quite sure that the Earth is not the stationary center of the universe, and that the planets including the Earth go around the sun. Consequently we must seek another explanation of the westward or retrograde motion of the planets. We are now quite sure that this retrograde motion of the members of the Sun's family is not real, but apparent; that the planets always move from west to east around the Sun; and that they only *seem* to move westward periodically for a short time when they are closest to the Earth. To take Mars again as an example: when it is nearest the Earth—that is, when it is on the opposite side of the Earth from the Sun—it seems to move westward for a few weeks, because the Earth is moving in the same direction around the Sun, but at a greater speed on a path that is shorter, being inside the orbit of Mars. The Earth goes around the Sun in 365¼ days, while Mars requires 687 of our days to make its journey.

It may make the matter clearer to compare the Earth to an express train and Mars to an automobile truck traveling in the same direction on a highway that parallels the railway. As the express train is



THE SUN AND ITS FAMILY

Chart showing the order of the nine major planets in relation to the Sun and to each other.

overtaking and passing the truck, a passenger would see the truck projected against the landscape beyond in such a way that the truck would appear to be moving backward. In the same way, Mars when observed projected against the background of the stars seems to be moving westward as the Earth passes by.

As shown by Kepler, the planets all move around the Sun in elliptical orbits, the Sun being at one focus of each ellipse. It is true that all the elliptical paths of the major planets are nearly circular in shape.

Of all the planets, Mercury is closest to the Sun, being only 36,000,000 miles away. Mercury has no moons that are known, and it is thought that, if any exist, they would have been discovered by photography through a telescope at a transit of this planet across the face of the Sun. Incidentally, the only planets that can transit or pass between us and the Sun's disc are those having their paths inside of the Earth's orbit, namely, Mercury and Venus.

Mercury makes the trip around the Sun in eighty-eight of our days. As Flammarion points out, a centenarian on Mercury has lived but twenty-four of our years. It is believed that Mercury always keeps the same side toward the Sun just as our Moon does toward the Earth. Therefore, it must rotate on its axis in exactly the

same time that it takes to go around the Sun.

The side of Mercury which is always turned toward the Sun is evidently very hot. By means of the thermocouple, the temperature has been measured, and it has been found to be over 600 degrees Fahrenheit, hot enough to melt lead and tin.

Mercury has the most eccentric orbit of any of the planets except Pluto and that of some of the asteroids. This large eccentricity has made it possible to make one of the astronomical tests of the Einstein Theory of Relativity in the movement of its perihelion point, that is, the point on the orbit nearest the Sun.

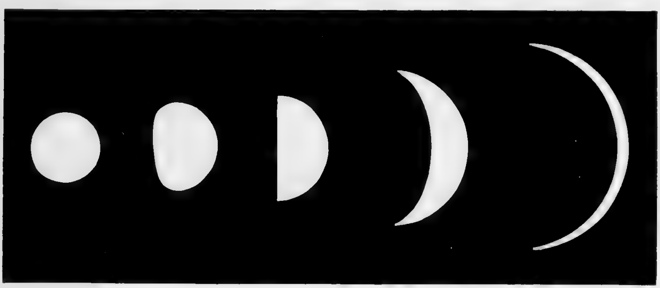
The telescope shows us that Mercury goes through all the phases that our Moon goes through, and, of course, it is for the same reason. Incidentally, the only planets that can pass through the crescent phases are those having their orbits inside that of the Earth, namely, Mercury and Venus.

Mercury is the smallest of the planets except the asteroids. Schiaparelli, the Italian astronomer, discovered some faint markings on Mercury which he thought to be permanent. Barnard described these markings as "very much resembling those seen on the moon with the naked eye." Lowell drew them more definitely as streaks. Antoniadi has confirmed Schiaparelli's work with the 32-inch refracting telescope at Meudon, near Paris. Certain permanent markings are so well known that a chart of the planet's surface has been drawn by him.

Mercury has very little atmosphere, and for this reason and also because of the high temperature on the side toward the Sun, can have no life as we know it on the Earth. According to Antoniadi, however, the atmosphere although very tenuous seems to support clouds of dust which are made visible by the temporary obscuration of the surface beneath,—that is, the darker permanent details are hidden at times by shifting dust formations.

Venus is second in order from the Sun, and for us is the brightest of the planets,—in fact, the brightest object in the sky except the Sun and the Moon. When at or near its greatest brilliancy, it can easily be seen in the daytime sky in full sunshine. In size it is very nearly equal to the Earth; in fact, Venus has been referred to as the twin-sister of the Earth.

Venus goes around the Sun in 225 of



VENUS

This shows Venus approaching the Earth. When she first comes into the evening sky she appears close to the Sun and shows nearly a full disc in the telescope. As she approaches us she appears larger and less fully illuminated, and, up to the time when she is a "half-moon," is seen farther from the direction of the Sun. Thereafter she seems to approach the Sun again, becoming meanwhile an ever larger but thinner crescent. The proportions here, however, are not drawn to scale. This illustration and description from "Splendour of the Heavens," published by Hutchinson & Co., London.

our days, and it comes closer to the Earth than any other of the major planets, approaching nearly 10,000,000 miles closer than Mars. The rotation period is not very definitely known, the evidence not being conclusive. From all the observed phenomena, the opinion reached at present is that Venus' rotation period is likely several weeks, being neither short like the Earth's, nor very long like Mercury's.

Like Mercury, Venus goes through all of the phases that our Moon goes through. The first person to see the phases of Venus was Galileo, these having been one of his earliest telescopic discoveries. According to the old Ptolemaic, or Earth-centered theory of astronomy, Venus was believed to travel around the Earth *inside* the Sun's orbit around the Earth. Since the lighted side of Venus must always be turned toward the Sun, and since Venus never traveled as far as ninety degrees away from the Sun in the sky, it is evident that it should not have exhibited any except crescent phases. But Galileo observed Venus in the gibbous phase, and this proved to be the most serious blow to the Earth-centered theory of Ptolemy. The precarious position of science in those days is indicated by the fact that Galileo announced his discovery in an anagram.

Venus has no known moons, and as in the case of Mercury, it seems probable that if there were any of considerable size, they would have been discovered at a transit of Venus.

Transits of Venus were formerly used in calculating the distance of the Earth to the Sun, the method having been first pointed out by Halley of Halley's Comet fame. These transits, however, are not of frequent occurrence,—the last was in 1882, and the next will be in the year 2004.

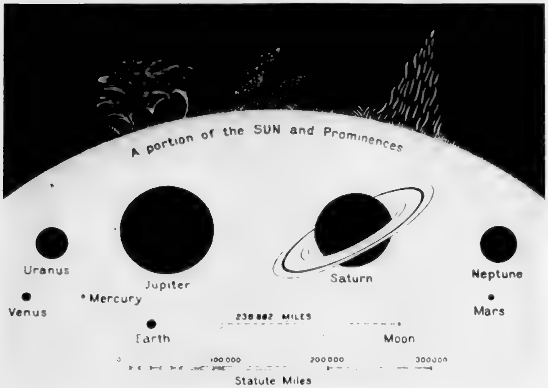
The temperature of the dark side of Venus has been found to be about 13 degrees below zero, Fahrenheit, and the bright side is only a few degrees higher. This is probably due to conditions similar to those which prevail in the Earth's stratosphere, for the measures of the temperature of Venus refer to the upper regions of its atmosphere or the upper surface of the bright envelope of cloud which surrounds this planet.

Venus is perpetually covered with a dense atmosphere, and this cloud-covered surface is responsible for the great brilliance of the planet, but it is at the same time a great drawback to terrestrial astronomers because it hides from view the detail on the surface beneath. Were it not for this heavy blanket of clouds, we should know much more about physical conditions on this interesting globe. Only a few elusive details are now and then seen in the telescope.

Although Venus has an atmosphere, it has not been possible to detect oxygen or water vapor in this atmosphere. If these exist, they must be below the outer reflecting layers. One of the recent discoveries of astronomy, however, has been that there are large quantities of carbon dioxide in the atmosphere of Venus, which fact may have some bearing on the question whether or not there is life on this planet. Both plants and animals give off carbon dioxide in the process of respiration, while green plants consume carbon dioxide in the process of photosynthesis.

Third in order from the Sun is our world, the Earth, one of the smaller planets,—four of the major planets being much larger and four being smaller. It is almost a perfect sphere, with a mean diameter of 7,920 miles. Careful measurements, however, have shown that the polar diameter is about 27 miles shorter than the equatorial diameter. This flattening at the poles, which is also noticeable in telescopic views of Jupiter and Saturn, is no doubt correlated with the origin and development of the planet.

From telescopic observation it is evident



THE SUN AND ITS SATELLITES
Chart showing the relative sizes of the Sun, Moon, and Major Planets.

that the other planets are round, and there are at least four easily observable proofs that our Earth also is round. Men and women have traveled around it by sea, by sea and land, and by air. At a lunar eclipse the shadow of the Earth on the Moon is always circular regardless of which side of the Earth is turned toward the Sun. When a ship sails away from an observer, the hull disappears first and afterwards the upper parts of the ship, the opposite effect being noticeable when a ship approaches from a distance. The appearance of the night sky changes as one travels northward or southward; for example, an observer in northern latitudes will see more and more stars come into view as he travels southward toward the equator.

The weight of the Earth in metric tons is represented by the number 6 followed by 21 cyphers. Its density is about $5\frac{1}{2}$ times that of water, and this is greater than the density of the outer crust. This fact, together with the behavior of earthquake waves, as shown by the seismograph, and with the consideration of the magnetic properties of the Earth, has led many astronomers and geologists to believe that the central core is solid nickel-iron. The composition of the nickel-iron meteorites is thought by some to lend support to this theory.

Between three-fourths and four-fifths of the Earth's surface is covered with water, and the globe is surrounded by a blanket of atmosphere, shown by measurements of the Northern Lights to be nearly 600 miles thick.

The Earth rotates on its axis once in 24 hours, and this causes the daily rising and setting of the Sun, Moon, stars and other heavenly bodies. The rotation of the Earth can be proved by Foucault's Pendulum, and it is also shown by the gyro-compass. Explanation of these instruments may be found in advanced textbooks of physics or astronomy.

While the Earth is spinning on its axis once every 24 hours, it is also traveling around the Sun once every year. In its orbital motion, it is traveling about 18 miles a second,—the speed of a rifle-bullet being about one-half mile a second. The

Earth's revolution around the Sun can be proved by exact measurements of the aberration of light, the annual displacement (parallax) of the nearer stars, and the annual variation in the speed with which stars are approaching or receding from the Earth.

The Earth's axis is inclined to the plane of its orbit, being 23½ degrees from a vertical to that plane. If it were not for this inclination of the axis, there would be no shifting northward and southward of the direct rays of the Sun, and consequently no change of seasons on the Earth.

The Earth has one large satellite, the Moon, which is a little more than two thousand miles in diameter. The Moon is the nearest heavenly body to the Earth except the meteors, its average distance being about 240,000 miles. It revolves around the Earth in about four weeks and rotates on its axis in exactly the same time as that of its revolution. Its motion around the Earth from west to east causes it to rise about fifty minutes later every day. It has very little, if any, atmosphere or water. Through a telescope one sees on its surface ranges of mountains, level plains, and thousands of craters. The Moon is concerned with every eclipse, and it is the chief cause of tides on the Earth.

Next outside our Earth is Mars, the ruddy planet, which has about half the diameter of the Earth and about twice the diameter of our Moon. On account of its smaller mass, gravity on Mars is less than on the Earth. A man weighing 150 pounds on the Earth would weigh 57 pounds on Mars.

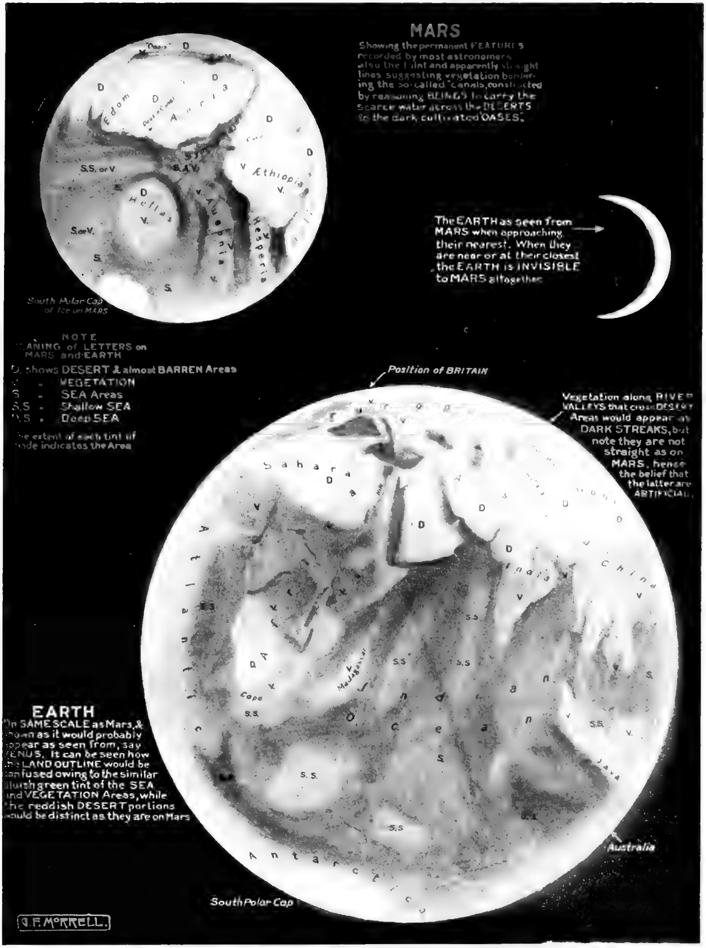
The ruddy planet revolves around the Sun in 687 of our days, the Martian year being nearly twice as long as ours. Since Mars has its orbit outside that of the Earth, it cannot go through the crescent and half-moon phases as seen from the Earth, but it does present the full and gibbous phases.

The rotation of Mars on its axis can be plainly shown by photographs through a large telescope under good conditions. Visual observations, too, are not very difficult to make for this purpose. Photographs, made as much as an hour or two apart, when compared, will furnish indisputable evidence. The large number of rotations that have occurred during the long time since Mars has been under close observation has made possible the determination of the period of rotation to within an extremely small margin of error. This investigation has shown that Mars rotates on its axis in almost exactly the same time as the Earth.

The inclination of the axis of Mars to the plane of its orbit is almost exactly the same as that of the Earth to the plane of its orbit,—probably a coincidence, as in the case of the time of rotation of the two planets.

Since Mars revolves around the Sun and since its axis is inclined to a perpendicular to its orbit, it must undergo change of seasons, as the Earth does. However, since its year is nearly twice as long as ours, each of its seasons must be nearly twice as long. Evidence of change of seasons can be seen with a large telescope under good conditions in the periodic expanding and shrinking of the polar caps (which behave in this respect like those of the Earth), and in change in color over large areas of the planet,—which may be analogous to or the same as our autumnal coloration on the Earth.

Schiaparelli, at an opposition of Mars in 1877—that is, when Mars was on the opposite side of the Earth from the sun—glimpsed markings on the ruddy planet which he called "canals." Since that time these so-called canals have given rise to much discussion among astronomers. Some astronomers virtually denied the existence of the markings, while others accepted the interpretation of Schiaparelli at full value.



Courtesy N. Y. Public Library

MARS AND EARTH COMPARED

A drawing of Mars compared with an imaginary view of the earth as it would probably appear from, say Venus. The difficulty of making out definite outlines is evident. When the Earth and Mars are closest together, the Earth would be invisible from Mars, because the unlighted or night-side of the Earth would be turned toward our ruddy neighbor. Drawing by G. F. Morrell.

Perhaps most astronomers were more or less skeptical.

Lowell and his followers believed that this intricate, geometrical network of markings could not have had a natural cause, but that it was artificial,—a system of canals dug by intelligent beings, canals to carry water from the melting ice-caps over the planet in a great irrigation enterprise. Although this is an amazing conclusion, there are a number of facts which fit in with this theory, namely: there are no mountains on Mars to interfere with these hypothetical canals, there are no oceans on Mars, there is little moisture in the atmosphere of Mars and few clouds, and with the progress of the seasons, when a polar cap began to shrink (melt), a darkening and widening of the canals (markings) was seen to progress from the polar cap over the planet.

Lowell calculated how wide these canals would have to be in order to be visible from the Earth with our largest telescopes, and he found they would have to be from ten to twenty miles wide. But Lowell did not believe that intelligent Martians had constructed a system of canals from ten to twenty miles wide extending over most of the planet. Rather he considered a canal proper too narrow to be seen from the Earth, but that what we see is a wider streak due to vegetation growing along the sides of the canal.

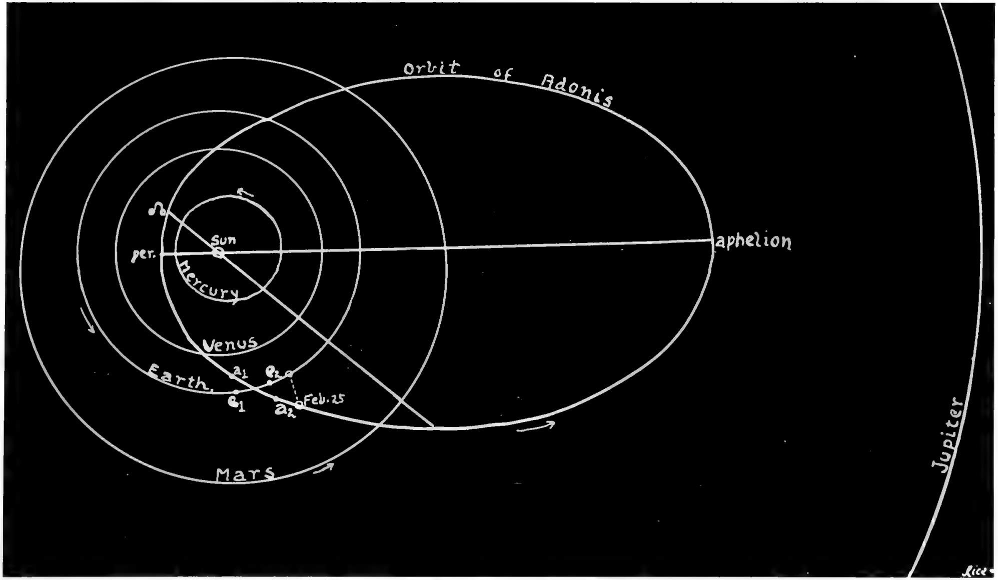
At the same favorable opposition at which Schiaparelli discovered the so-called canals of Mars (in 1877), Asaph Hall, the elder, discovered two tiny moons revolving around Mars. The discovery was made through the large 26-inch refracting telescope at the U. S. Naval Observatory. When discovered, these satellites were the smallest heavenly bodies known except the meteors. The outer one is estimated to be five miles in diameter and the inner one ten miles in diameter.

The question of perennial interest about Mars is whether or not there is life on the planet. The answer depends in part upon conditions. Without doubt, Mars has an atmosphere. By indirect spectroscopic investigation, we know this atmosphere contains both oxygen and water vapor, but both in much smaller amounts than they occur in the Earth's atmosphere. By means of the thermocouple the temperature of Mars has been carefully measured, and it has been found to be high enough to support some forms of life that we know on the Earth.

It seems now to be the consensus of opinion among astronomers that very probably there is life on Mars, at least plant life. And since plant and animal life developed together on the Earth, perhaps they have also done so on Mars.

It is of interest to reflect that we know more about Mars than we do about Venus, although the latter is a nearer neighbor. In the first place, when Mars is nearest the Earth, the bright side is turned fully toward us, while Venus has its bright side turned away from the Earth when it is nearest to us. And secondly, the atmosphere of Mars is very transparent while that of Venus is opaque.

Between the orbit of Mars and that of the next large planet outside, there have been found many bodies known as asteroids or minor planets, all of which revolve around the Sun in the same direction as the major planets. About 1400 have been catalogued, and it is estimated that there must be altogether many thousands in this zone. Ceres, the largest one, is nearly 500 miles in diameter. They range in size from Ceres down to the smallest known, Adonis, which is estimated to be less than one-half mile in diameter. In all probability there are thousands still smaller,—too small to be observed with our present equipment. Vesta, although only the third largest, is the brightest of the asteroids, and when



A PLAN VIEW OF THE ORBITS OF SEVERAL PLANETS AND THE NEWLY-DISCOVERED MINOR PLANET ADONIS

These orbits are roughly drawn to scale and the eccentricity of Mercury's orbit is seen. The cometary nature of the asteroid's orbit is also in evidence, the aphelion being a little over halfway between Mars' and Jupiter's orbits. A study of the positions of the asteroid and the Earth at the points a^1, e^1, and later a^2, e^2, show how within a few days in early 1936 the positions of the planetoid changed in direction to entirely different parts of the sky. (Diagram from Hugh S. Rice.)

nearest the Earth is sometimes visible to the unaided eye.

Although the asteroids occupy a belt outside of the orbit of Mars, the orbits of a few of them are so eccentric that they approach nearer the Earth than Mars or even nearer than Venus. The perihelion of Amor is inside the Earth's orbit, and that of Apollo is even within the orbit of Venus. Adonis, at a distance only a little more than 1,200,000 miles,—reaches its closest approach to the Sun within the orbit of Venus and near the orbit of Mercury. Hermes, discovered in 1937 by Reinmuth, comes closer to the Earth than any other known asteroid, approaching within 400,000 miles.

The orbit of Eros, which comes within 14,000,000 miles of the Earth, has furnished the astronomer an accurate yardstick for calculating the distance of the Earth from the Sun.

A tiny asteroid, 5 miles in diameter, discovered by Reinmuth in 1931, has been named Riceia in honor of H. S. Rice, Associate in Astronomy in the American Museum of Natural History, in recognition of his careful studies of these interesting bodies.

Of the principal planets (that is, other than the asteroids), Jupiter is fifth in order of distance from the Sun. Being the largest member of the solar family, it has a diameter eleven times that of the Earth. In fact, it is larger than all the rest of the planets put together. The surface gravity is between two and three times as great as that on the Earth. When closest to the Earth, Jupiter is brighter than any other planet except Venus and occasionally Mars; at such times it casts perceptible shadows of terrestrial objects.

With even a small telescope, one may see distinct belts in the atmosphere of Jupiter running parallel to its equator. By observation of these belts and other markings, which are more or less permanent, it has been determined that this giant rotates on its axis in less than ten hours, the shortest period of rotation known among the planets. No doubt this rapid rotation is correlated with the very noticeable bulge at the equator and flattening at the poles, observable in a small telescope. While Jupiter rotates on its axis at this rapid speed, it takes nearly 12 of our years to revolve around the Sun.

Courtesy of Yerkes Observatory

JUPITER

Showing cloud bands, large red spot, and shadow of one of the Galilean moons. Drawn by Barnard. May 26, 1908.

It is quite certain that we see only an outer surface of cloud, probably clouds of solid crystals or liquid droplets of ammonia in an atmosphere of methane on this planet. Both ammonia and methane (a gas known as fire-damp when it occurs in mines) have been identified on Jupiter by indirect methods of spectroscopy. For

THE UNIQUE RING OF SATURN
Drawing of Saturn showing different phases with respect to its ring. (After Proctor.)

many years it has been known that Jupiter rotates faster at the equator than at higher latitudes. On this account, it was formerly believed that the planet was highly heated and plastic, but since the invention of the thermocouple, the surface temperature of Jupiter has been measured and has been found to be very low, about 200 degrees below zero, Fahrenheit. It is now believed that this difference in rotation speed is correlated with the fact that Jupiter presents only an outer surface of clouds.

In 1610 Galileo discovered four large satellites revolving around Jupiter, and these are still known as the Galilean moons. Since Galileo's day five other satellites, all quite small, have been discovered. The inner seven of these satellites revolve around Jupiter in the same direction in which the planet rotates, but the outer two revolve in the retrograde direction. It has been suggested that the outer two may be captured asteroids.

Saturn is the sixth planet in order from the Sun. It is next to Jupiter in size. To the naked eye it looks like a dull yellow first magnitude star. Because of its unique series of rings, it is considered by many persons to be the most beautiful telescopic object in the sky. Galileo's telescope was not good enough to reveal the shape of these rings, and it was not until 1655 that Huyghens perceived the true shape and position of the rings. Formerly the rings were believed to be hot, and were referred to as the fiery rings of Saturn. They were then considered as evidence in favor of the nebular theory. Recent investigation has shown that the rings are made up of myriads of tiny solid bodies or "moonlets," and of course they are very cold.

Around Saturn there are faint belts parallel to its equator. Also there are more or less temporary spots, which have made it possible to determine how long it takes Saturn to rotate on its axis, and this period is a little more than ten hours. Saturn is even more oblate than Jupiter. The period of revolution around the Sun is nearly 30 of our years. When we observe Saturn in the constellation of The Fishes (where it is in 1938) we may reflect that it will require 29½ years for the planet to travel around the sky to this place again.

The surface temperature of Saturn is nearly 240 degrees below zero, Fahrenheit. Ammonia and methane have been identified in the atmosphere of Saturn, as they have in Jupiter.

Saturn has nine satellites, eight of which revolve around the planet in the direction in which it rotates on its axis. The ninth satellite, however, revolves backward, as do the outermost two of Jupiter.

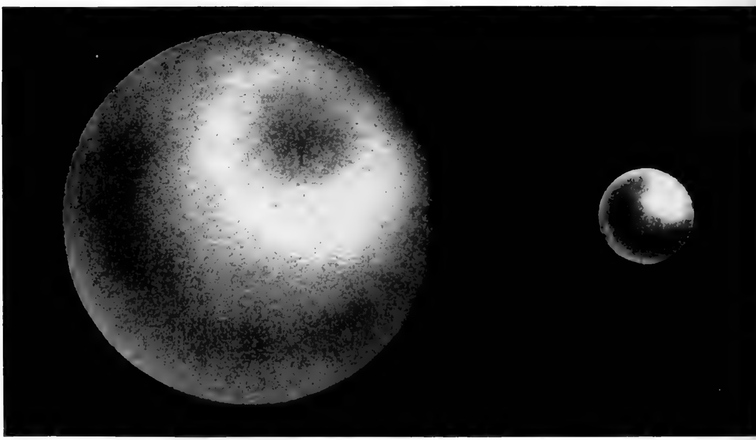
Uranus, the seventh planet from the Sun, was the first to be "discovered." It was found accidentally in 1781 by William Herschel, who at first thought it was a comet and so reported it. After it was proved to be a planet, Herschel wanted to name it "Georgium Sidus" in honor of

King George III. Many other astronomers called it "Herschel," but finally the name "Uranus," proposed by Bode, was adopted. The planet was discovered in the constellation Gemini with a 7-inch reflecting telescope made by Herschel himself. It is about sixth magnitude, and under idéal conditions is just visible to the naked eye. In color it is apple-green.

Uranus takes about 84 of our years to go once around the Sun. Its time of rotation has been determined by V. M. Slipher to be about 10¾ hours. Uranus has four satellites, which are inclined 82° to the plane of the planet's orbit, and their revolution is retrograde. The rotation of the planet on its axis seems to be in the same plane as that of the orbits of the satellites, and it is also retrograde, unless we look upon the inclination of the axis of Uranus as a little more than 90°, as it would be if measured from the other side.

The discovery of the eighth planet, Neptune, is perhaps the most dramatic achievement in the history of astronomy. The honor of discovery is shared by two young mathematical astronomers, Adams, a student of the University of Cambridge, and Leverrier of Paris. It had been found that Uranus did not follow closely its computed orbit,—in fact, it behaved as though it were influenced by an outer planet. From the observed perturbations, these two astronomers, working independently, calculated the position of the hypothetical planet. Adams finished his calculations first, but there were delays in checking up at the Greenwich Observatory. Leverrier finished his work, and sent a message to Galle at the Berlin Observatory, who found the planet in a very short time within a degree of the point indicated by Leverrier.

The planet was discovered in 1846, and it was first named "Leverrier," but this name was soon superseded by the name



URANUS AND THE EARTH

The planet Uranus is nearly four times the diameter of our Earth, but is nineteen times as far from the Sun, so it receives 360 times less light. It was the erratic behavior of Uranus that led to the discovery of the planets Neptune and Pluto. Photo from "The Splendour of the Heavens," published by Robert M. McBride and Company.

"Neptune." Its period of revolution around the Sun is about 165 of our years. Its period of rotation on its axis, determined spectroscopically, is about 16 hours, and the direction is from west to east (direct), while the revolution of its only satellite, Triton, is from east to west (retrograde)—a surprising condition.

Eighty-four years after the discovery of Neptune, a ninth major planet was added to the solar family, having been discovered photographically at the Lowell Observatory, in following a program inaugurated by the founder of this observatory. Among other things, Percival Lowell had two especial purposes in mind when he established the observatory which bears his name,—first, to study Mars, second, to search for ultra-Neptunian planets. The first object was carried out very thoroughly during his lifetime, but in the second no tangible results were obtained until after his death. However, the program of search was carried on by V. M. Slipher, who succeeded to the directorship of the observatory.

After years of search, the new planet was photographed with the 13-inch astrographic telescope, and "picked up" on the plate with the aid of the "blink-microscope," by Clyde W. Tombaugh. This was in January, 1930, but the discovery was not immediately announced. Dr. Slipher and his associates wanted to be sure about the nature of the body. It might be a comet, as William Herschel at first thought Uranus to be. If it were a comet, it would be found to be moving rapidly toward or from the Sun, unless at or near the outer end of its long elliptical orbit. It would take a little time to be sure about this point.

After some seven weeks of careful observation and computation, the Lowell Observatory astronomers became thoroughly convinced that the new body was a planet, and its discovery was announced on March 13, 1930, the birthday of Percival Lowell. Many astronomers wished to have the new planet named "Lowell," but, in view of the experience in naming Uranus and Neptune, it seems fortunate that this was not done. Instead, the Lowell Observatory astronomers decided upon the name "Pluto," the god of darkness, an appropriate name since the new planet is so distant from the Sun that it receives very little light from that central luminary.

However, it is to be noted that the symbol for the new planet, which is used by the United States Naval and other observatories, is made up of a combination of the first two letters of the name "Pluto," and that these two letters are the initials of Percival Lowell.

By measuring its movement against the background of the stars from night to night, and making the necessary allowances, it was possible to compute its period of revolution around the Sun. This period has been found to be about 248 years. Then by using Kepler's third law of planetary motion, the so-called Harmonic law, its distance from the Sun has been determined to be nearly 4,000,000,000 miles. Its relative brightness gives some clue to its size, and it is believed to be smaller than the Earth. It is yellowish in color, but it cannot be seen except through our largest telescope. It has the most eccentric orbit of all the planets. In 1989 it will be closer to the Sun than Neptune, but at that time it will not be very close to Neptune.

The first institution in the world to establish a model of the Solar System of large size in combination with a Zeiss Projection Planetarium was the famous Deutsches Museum in Munich. Its director, the late Oskar von Müller, generally considered to be the leading museum man of this generation, believed that these two instruments would supplement each other, that they were necessary to each other in making a

complete unit. The Curator of the Hayden Planetarium is indebted to Dr. von Müller for this idea, and the experience of more than two years has convinced us of the correctness of his conclusion.

This model of the Solar System is known as a Copernican Planetarium, so called because it shows the planets and the central Sun according to the Copernican system of astronomy, which system is now universally accepted. It was designed and built by J. W. Fecker of Pittsburgh.

With this three-dimensional apparatus, capable of simulating the motions of the real heavenly bodies, the observer is on the outside looking on, as it were,—and it is evident that he can get a clear and adequate idea of the working of the Solar System in a few minutes. We believe that a short time spent with this model in the large circular room on the first floor of the Planetarium building will make the demonstration with the Zeiss Projection Planetarium in the dome on the floor above more understandable and more enjoyable.

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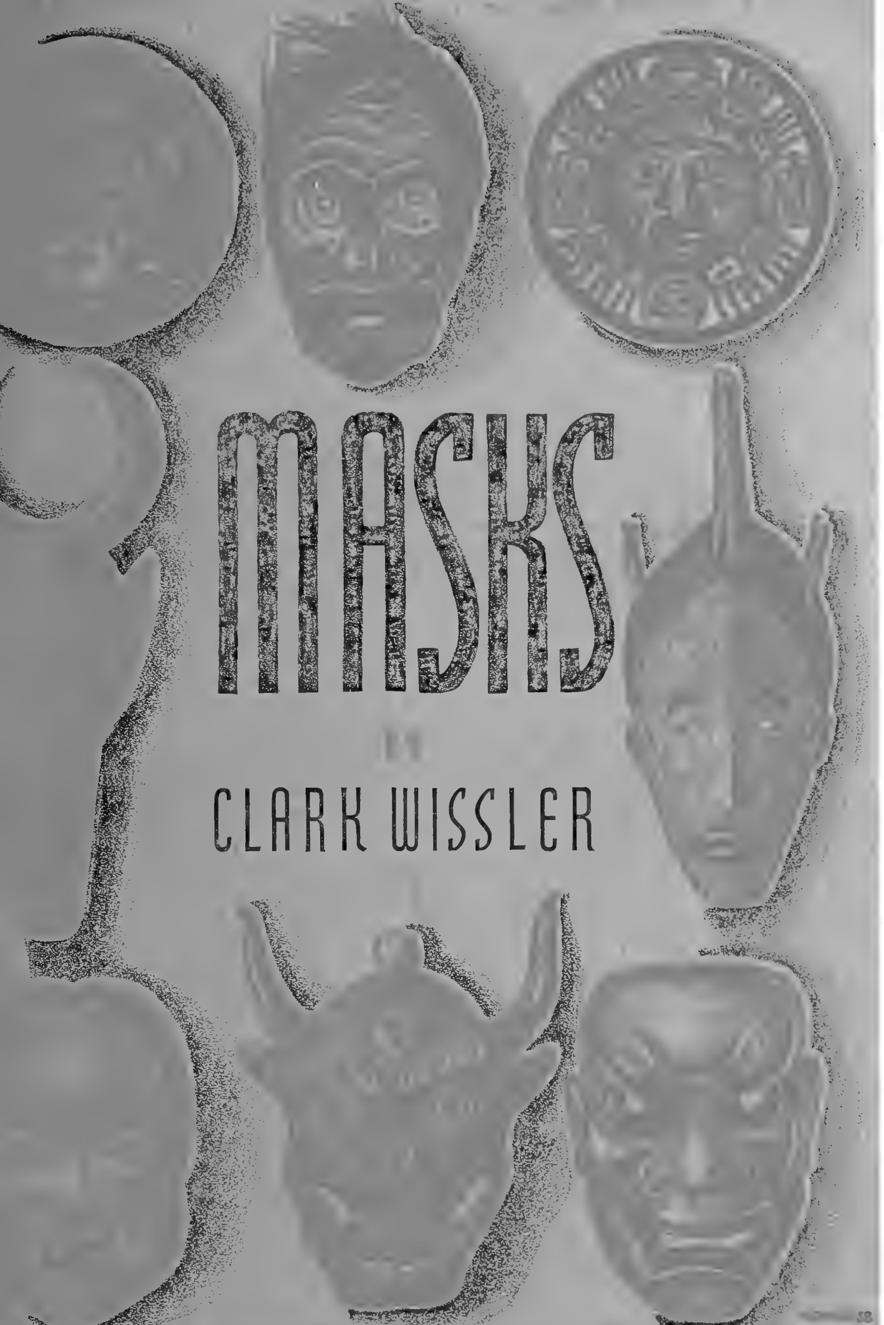
NEW YORK

MASKS

BY

CLARK WISSLER



NEW YORK

Issued under the direction of the Committee on Popular Publications.

ROY W. MINER, *Chairman*

MASKS

By

CLARK WISSLER, Ph. D.
Curator of Anthropology

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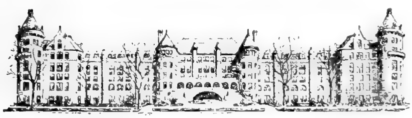

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A DEVIL DANCER

In Tibet the Devil Dancers appear at the end of the year, impersonating the gods who expel the demons of bad luck. The dancer represented here wears the mask of Marbo, one of the three attendants of the Lord of Hell.

MASKS

By CLARK WISSLER

THE use of "false faces," or masks, is an old trick of the human race. The museum visitor, viewing the weird and often grotesque masks on exhibition, may be moved to speculate as to the meaning of these caricatures and to wonder why so much space is allotted them. For example, an exhibit concerning the Iroquois Indians of New York is certain to contain a number of curious masks, because these Indians maintain a unique society for men known to us as the False Face Society. This name calls attention to the most striking outward feature of this society, the wearing of masks.

There is something impressive in Iroquois "false faces," as many museum visitors have testified; they have a striking individuality, especially in the treatment of the eyes and the mouth. Carved upon the trunks of living trees, depicting a face with cavernous eye holes, strong nose, and protruding lips, the face framed in with long hair falling loosely from a wig: such images peering from the shadows of the open fire, around which Indians love to gather, impress themselves too deeply upon the mind to be forgotten. Those of our readers who saw the play "Hiawatha," as presented some years ago, or the film made from it, will recall the striking entry of the False Face dancers, their slouching gait, and above all, their strange, awful mien. (Figs. 1-3)

But the Iroquois are not the only Indians who use masks; on the contrary, the practice is widespread. The totem-pole makers of Alaska and Vancouver Island also are celebrated for their wooden masks, which far excel in variety and size those of the Iroquois. Visitors to museum collections may note these wooden masks, painted in black, red, and green, especially a few huge masks, seemingly too large and heavy for one person to support.

The masks of the Iroquois represent faces essentially human, whereas these larger masks of the totem-pole makers depict animal and bird monsters. Not infrequently the jaws of these masks are hinged so that the dancers can open and close them at will, and often when the mouth of the mask is opened in this way, a human face appears within. This is not, however, altogether a matter of fancy for throughout the myths of primitive folk runs the idea that those who have power can change at will from human to animal form and back again. (Figs. 44-47)

Thus the frequent reader of Indian tales is familiar with such incidents as "Now a raven appeared and spoke to

(Continued on page 3)

NEW YORK

Figure 1
Iroquois mask, made of cornhusks.

Figure 2
Iroquois mask of wood.

According to the Iroquois belief, these masks represent spirits or supernatural beings which have power to frighten away evil and disease. Thus when they enter the village or a house they are believed to make it a safe place to live in.

Figure 3
IROQUOIS FALSE FACE SOCIETY, ENTERING THE DANCE LODGE.

Figure 4—A clay head, a prehistoric example of modeling from Vera Cruz, Mexico.

him, but as the raven came nearer, it became a person standing there." Certain large wooden masks of the Indians of Vancouver Island are so constructed that the dancers are able to demonstrate such a supernatural transformation of the mythical raven into a person; the outward forms of these masks represent the raven, but when concealed cords are pulled by the wearer, the raven face of the mask opens, and that of a human appears inside. Few peoples have carried this idea out so ingeniously in the construction of their masks as have these wood-carving Indians of Alaska and the Canadian Coast.

J. G. Swan, one of the early visitors to these Indians, writing as an eyewitness, says,

. . The masks are made of alder, maple, and cottonwood; some are very ingeniously executed, having the eyes and lower jaw movable. By means of a string the performer can make the eyes roll about, and the jaws gnash together with a fearful clatter. As these masks are kept strictly concealed until the time of the performances, and as they are generally produced at night, they are viewed with awe by the spectators; and certainly the scene in one of these lodges, dimly lighted by the fires which show the faces of the assembled spectators and illuminate the performers, presents a most weird and savage spectacle when the masked dancers issue forth from behind a screen of mats, and go through their barbarous pantomimes. The Indians themselves, even accustomed as they are to masks, feel very much afraid of them, and a white man, viewing the scene for the first time, can only liken it to a carnival of demons.

However, it was not alone the totem-pole-carving Indians of Vancouver Island and Alaska who indulged in such impressive and picturesque pastimes, for the Aztec of Mexico, their predecessors, and the prehistoric Maya of Yucatan seemed

Figure 5
Mask from Tibet, representing a cow.

Figure 6
A Chinese mask.

to have specialized in masks. (Figs. 53, 54 and 57) The former have left behind a number of curious manuscripts in picture writing, showing gods and heroes wearing masks. The Maya were expert carvers in stone, covering their temple walls and stone monuments with carvings in low relief, among which may now and then be seen masked figures. (Fig. 52) Nor was it only among the peoples of the Americas that such masks were used; they were used in the Old World as well. In present-day China, India, Java, etc., one meets with processions and festivals in which masked figures play the chief rôle, for the most part survivals of ancient customs. (Figs. 55-56)

Often when observing a custom so widespread as the use of masks, the thought arises that here is something of special importance in the

(Continued on page 9)

Figure 7
In Tibet, the owl is regarded as a spy and so we have this interesting mask.

Figure 8
A Japanese actor wearing a mask representing a mythological character, spoken of as the "Wanderer."

Figure 9

The old "Woman of the Mountain." A Japanese character frequently seen in the theatre.

Figure 10
A Japanese mask worn by actors to represent a mythological bandit. The full stage costume of the actor is shown above.

Figure 11
A small clay figurine from Libertad, Chiapas, Mexico.

Figure 12
This is an impressive face showing unusual skill on the part of the carver. Lips drawn back, the hostile eye, and the protruding beak, all combine to give a ferocious look. Indians of British Columbia.

life of man, and a custom whose beginning dates back to the dawn of civilization. At any rate, a custom that appears to be world-wide and ancient seems to be worthy of serious study.

Turning again to the Iroquois Indian False Face Society, we note that there are in this company at least four classes of false faces: doorkeeper faces, those worn by doctors when treating the sick, the beggar masks, and what are spoken of as secret masks. Many individual masks have names according to the mythical being they represent, usually certain stone giants that play a large rôle in the beliefs of these Indians; one of the myths accounting for the origin of the Go-gon-sa false face was recorded by Mrs. Harriet Maxwell Converse as follows:

It could see behind the stars. It could create storms, and summon the sunshine. It empowered battles or weakened the forces at will. It knew the remedy for each disease, and could overpower Death.

Figure 13

Figure 14

JAVANESE FESTIVAL MASKS

The Javanese are skilful mask makers. Their masks are expressive, and usually elaborately painted. They are favorites of collectors, many persons having built up large private collections, probably because Javanese mask makers look upon their work as art rather than as magic and religion. The prevailing colors are red, black, orange, gold, and white

Figure 15

Figure 16

The Bella Coola Indians, British Columbia, carried the making of masks to an extreme. Wood was the chief material so the masks were, in part, an expression of art in wood carving. Skilful painting emphasized the facial features. As usual with primitive mask makers, the forms were standardized because each represented a mythical being, with a name and individual characteristics, known to most members of the tribe.

It knew all the poison roots and could repel their strong evils. Its power was life, its peace the o-yank-wah, the tobacco which drowsed to rest. The venomous reptiles knew its threat and crept from its path. It would lead the young hunter back to his people when the Stone Giant directed. It said: 'My tree, the basswood, is soft, and will transform for the molder. My tree wood is porous, and the sunlight can enter its darkness. The wind voice can whisper to its silence and it will hear. My tree wood is the life of the Go-gon-sa. Of all in the forest there is none other.'

With this knowledge, the young hunter started on his way carving go-gon-sa-so-oh, (false faces). From the basswood he hewed them. By the voice of the Stone Giant he was guided to choose; and well he learned the voices of all the forest trees before he completed his task.

In his travels he met many strange animals and birds, which he detained until he had carved them in the basswood; and inviting them to tarry, learned their language and habits; and though fearing the Giant's reproval, for he constantly heard his voice encouraging or blaming, he learned to love these descendants of his ancestors, and was loath to leave them when compelled to return to his home.

Many years had passed in the laborious task, and he who entered the cave a youth, had become a bent old man when, burdened with the go-gon-sas he had carved, he set out on his return to his people. Year after year his burden had grown heavier, but his back broadened in strength, and he had become a giant in stature when he reached his home and related his story. (Figs. 1-3)

In a general study of masks, the first questions to arise are, "What place do masks hold in the interest of primitive peoples? What kind of ideas and beliefs are associated with them?"

If we begin with our own civilization and time, we see the mask as a frivolous object; the clown or the silly buffoon may use it to heighten his grotesqueness; children and young people may use masks on fête days to amuse adults and to frighten the timid. Occasionally they are still used upon the stage when some of our ancestral folklore is to be enacted. (Fig. 35)

Yet, on the whole, the mask is to us

(Continued on page 15)

Figure 17
A mask from Java.

Figure 18
A masked figure representing the mystic serpent in Japanese mythology.

Figure 19
A Japanese stage mask representing a male demon.

Figure 20
Japanese mask representing the jolly woman.

Figure 21
Representing a female demon.

Figure 22
Representing a mythological character, known as the whistler.

JAPANESE MASKS

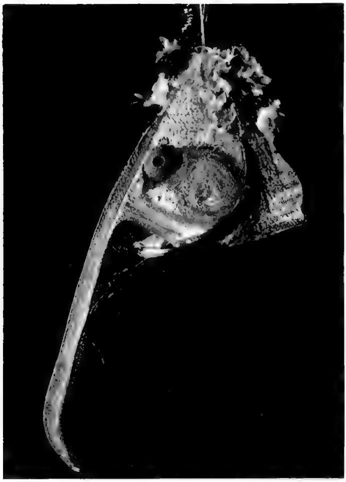

Figure 23—A long-nosed mask from the Sepik River people of New Guinea who regard such noses as a mark of beauty.

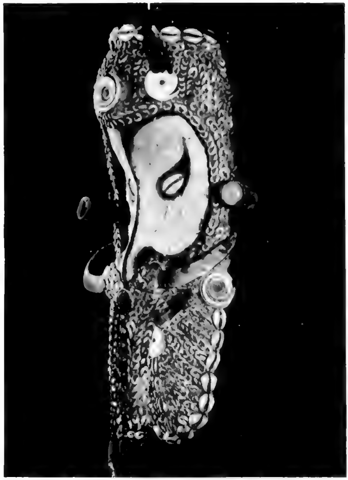

Figure 24—Many New Guinea masks are overlaid with shell; often the design is sufficiently delicate to produce an unusually beautiful type of mask.

Figure 25—This large wooden mask from New Guinea is of the type used as a gable decoration to a house.

Figure 26—A mask of plaited materials.

NEW GUINEA MASKS

Figure 27

Figure 28

Figure 29

Figure 30

A GROUP OF AFRICAN MASKS

Figure 31
Plains Indian Dog Dancer, drawn by Bodmer. This is not a masked figure but calls attention to the common New World practice of massive head and face costume, with the face of the wearer exposed, but modified by painting.

something childish, something scarcely to be considered respectable. Consequently, when we stand before a museum case, or look over the pictures in a book, we are puzzled how to justify the attention given to the subject of masks by serious-minded people; we may go even further and assume that the people who made and used these masks were infantile in their interests, so far benighted as to be beyond understanding. This is in keeping with one of our bad intellectual habits, viz., attributing our own ways of thinking to the savage mind. Because we put no value upon masks, tolerating them only in light, frivolous associations, we fail to see how savages could regard them otherwise, even such savages of ancient Europe as were our ancestors.

When seriously used, masks are part of the regalia worn in savage ceremonies, chiefly religious. (Figs. 31-33) Such ceremonies may have many features, but most of them possess regalia and a ritual in which are songs and dances. Here, again, we often misjudge the savage, for to us a dance is anything but religious, and so his dancing upon such occasions, if it does

(Continued on page 20)

Figure 32
A Kachina Dancer. The tourist in New Mexico and Arizona is offered many appealing small wooden images or dolls, called Kachinas. Each of these has a name, the name of the supernatural being it represents. In the regular Kachina ceremonies of certain Pueblo Indians, men and women wear masks to impersonate these gods. Among the Hopi the number of such gods, or Kachinas, exceeds 150. The colors are usually green, white, black, red, and blue.

Figure 33
TWO MASK CEREMONIES OF THE NAVAHO INDIANS
At the left a man masked to represent a god is driving out disease by shaking his rattle over the patient, while the naked youth at the right is a novice undergoing an initiation rite.

Figure 34
PUEBLO INDIAN ALTAR SHOWING REPLICA OF MASKED DANCERS IMPERSONATING GODS.

Figure 35
A Christmas-time scene in England, apparently the survival of an old pagan festival in which dancers appear, wearing masks.

Figure 36
Totem poles in front of an Indian house, Southern Alaska. The large faces carved on these poles are in the same style as wooden masks used by the same Indians.

Figure 37

A mask and headdress. Swan's down, eagle tail feathers, and human hair are skilfully arranged on a wooden frame attached to the mask, which represents a dying man, with open mouth and protruding tongue. This mask was worn by a doctor during healing ceremonies. Northwest Coast Indians.

Figure 38

Face of a beaver on a box. While this is not a mask, the method and quality of the caricature are similar to that found in masks. Northwest Coast Indians.

Figure 39
A mask from New Ireland, neatly carved of wood. It is never safe to guess the functions of masks; thus in this little Island world they are worn in ceremonies to commemorate the dead.

Figure 40
This jolly face illustrates the spirit of masked dancing among the Eskimo and the Indians of Alaska.

Figure 41
A ceremonial mask from New Ireland.

Figure 42 *Figure 43*
The native people of Africa, many of them expert wood carvers, emphasize the human in their masks, though caricature is evident. Some are decorated with cowrie shells, but for the most part the artist depended upon the carving technique to produce the desired effect. Incidentally we note that among primitive peoples in all parts of the world, wood is the preferred material for masks; it is only among the more complex civilizations that plastic materials are used.

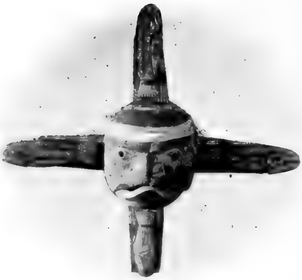

Figure 44 *Figure 45*

Two views of a Bella Coola mask. The Indians of British Columbia and Alaska delight in masks which are double or triple, as the case may be. First, as in Fig. 46, we see what seems to be the face of a fish, but when strings are pulled this face suddenly opens and reveals a human head.

not shock us, at least provokes pity for his lack of understanding. On the other hand, anthropologists who specialize in the study of primitive life, find in the regalia, songs, and dances what they regard as important data for the understanding of human life. (Figs. 13-26, 34, 36)

If the reader goes to a library and asks for special publications upon the American Indian, for example, long detailed studies of ceremonies will be given to him, describing minutely just how the participants were dressed, what they did, sang, and danced; further, an attempt will be made to explain the meaning of the ceremony. Any reference librarian can give a long list of such books, which means that many tribal ceremonies have been studied in every part of the world — Asia, South America, Australia, Africa, and elsewhere—and looking over these detailed descriptions of savage ceremonies, one finds them much alike. (Figs. 9, 19, 23, 29, 62)

No matter to what part of the world we turn, we find the belief that these ceremonies, songs, and dances were not designed by man, but were given to him ready made and in some mysterious fashion, just as in the case of the Iroquois Indian who started the False Face So-

Figure 46

A three-in-one mask from Vancouver Island: first, it appears as a large fish, but when the jaws of the fish open, we see the face and bill of a bird; finally, when these open, we see the face of a man.

Figure 47
A double mask from the Haida Indians.

Figure 48
A double mask from the Indians of British Columbia.

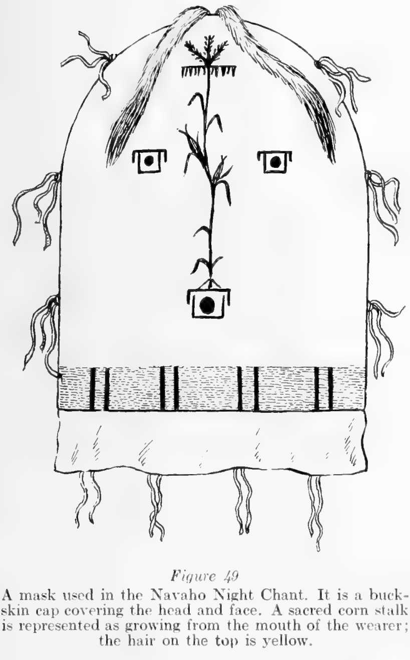

Figure 49
A mask used in the Navaho Night Chant. It is a buckskin cap covering the head and face. A sacred corn stalk is represented as growing from the mouth of the wearer; the hair on the top is yellow.

ciety. (Fig. 3) Someone, at some time—usually in the good old times now passed—met a supernatural being who taught him the whole ceremony.

For example, an interesting Indian tale recounts the experiences of a young man who wandered out alone. Coming at last to a place where the beavers had a dam and their houses in the water, he sat down to meditate. These beavers, he thought to himself, must possess some extraordinary power to do as they do, and so he resolved to sleep there, hoping that the chief of the beaver might take pity on him and help him to attain to a place of power and respect among his own people. That night a beaver appeared before him, turned into a person, and invited him to follow; they passed down into the water and into the house of the beaver. It was a great lodge and his guide was the chief of all the beaver. Here the young man saw many beaver and here he stayed throughout the winter as the

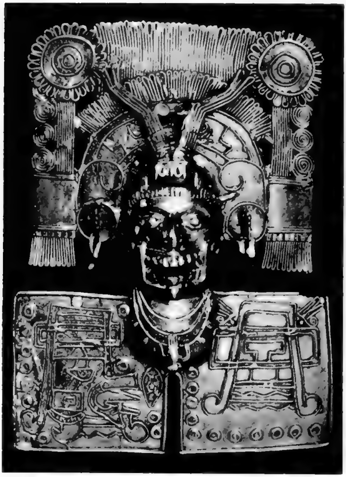

Figure 50
A gold figure representing a masked Tiger Knight. Monte Alban, Oaxaca, Mexico.

guest of the beaver. When spring came, however, the young man expressed a wish to return to his people. So the beaver called into his lodge all the head beaver and, becoming like people, they performed a ceremony, teaching the young man the songs, dances, etc. Then he was conducted to the dry ground, to his old camping place, and so returned to his people, where he started the ceremony he learned from the beaver.

When we review this tale, we note, first, that there appeared to the Indian a beaver which took on human qualities, because it spoke to the Indian and conferred upon him powers and imparted information, and so the Indian started a ceremony. But what is this ceremony like? It begins with a narrative like the preceding; then the leader of the ceremony takes the part of the beaver, other participants are the beaver's helpers and, finally, one person takes the place of the original hero, who is said to have been received into their lodge by the beavers. The ritual which follows is supposed to repeat the events, step by step, by which the beaver conferred this ritual upon the first Indian. In other words, the incident is staged with an appropriate cast and the participants become, in a way, players presenting a drama.

This not only applies to this particular ritual, but is well-nigh universal among mankind, primitive and civilized. Naturally rituals and symbolic procedures believed to have originated with mythical beings cannot well be demonstrated except through the impersonation of these mythical beings who, as we have stated, while often conceived of as animals or birds, are also human, having a kind of alternating personality, exceeding the power of real human beings as well as animals in that they can change their bodily forms and do other things impossible for either animals or humans.

Figure 51
A mask of gold representing the god, Xipe-Totec. Found in a tomb at Monte Alban, Oaxaca, Mexico. This is probably one of the most beautiful examples of prehistoric American art.

The wearing of a mask is the usual method of impersonating these mythical human beings or their animal counterparts. When the American Indian impersonates the buffalo, he may put the skin of the head over his own head, and look out through the eye holes; the effect may be heightened by having the whole skin fall over the shoulders of the wearer and down the back, the characteristic buffalo tail dangling below. Also the bear plays a part in the mythologies of many peoples and so is impersonated with great frequency; sometimes the face of the bear is realistically carved in wood, to which the skin of a bear is attached; drawing this over his head, the savage will crouch and growl, and by skilful acting give a satisfactory representation of a bear.

A spirited description of a masked Indian dance is given by George Catlin, the famous Indian traveler:

> My ears have been almost continually ringing since I came here, with the din of yelping and beating of the drums; but I have for several days been peculiarly engrossed, and my senses almost confounded with the stamping, and grunting, and bellowing of the buffalo dance. . . .
>
> Every man in the Mandan village is obliged by a village regulation to keep the mask of the buffalo hanging on a post at the head of his bed, which he can use on his head whenever he is called upon by the chiefs to dance for the coming of buffaloes. The mask is put over the head, and generally has a strip of the skin hanging to it, of the whole length of the animal, with the tail attached to it, which, passing down over the back of the dancer, is dragging

(Continued on page 25)

Figure 52

A Maya carving in low relief depicting a man wearing a mask and a magnificent headdress. Many Maya carvings are so skilfully executed that one can see the mouth and eyes of the wearer through the mask. This carving is from Seibal, Guatemala.

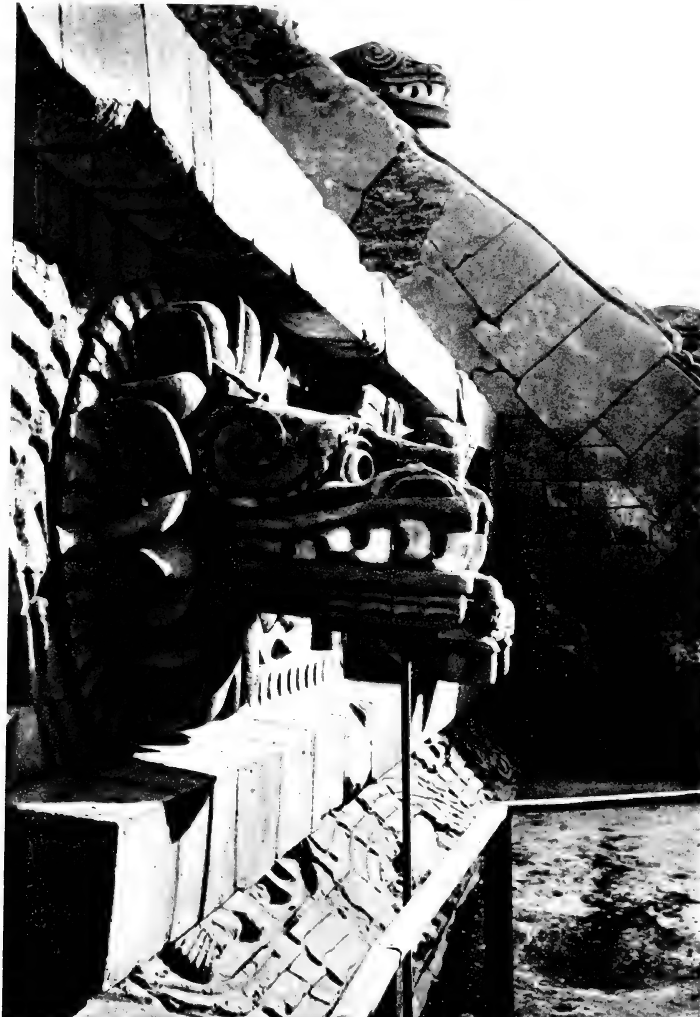

Figure 53
A stone carving on the ruined temple of Quetzalcoatl, Teotihuacan, Mexico, representing the Feathered Serpent.

Figure 54
Many ancient Mexican clay vessels are modeled to represent priests officiating in masks, thereby impersonating the gods.

on the ground. When one becomes fatigued of the exercise, he signifies it by bending quite forward, and sinking his body toward the ground; when another draws a bow upon him and hits him with a blunt arrow, and he falls like a buffalo —is seized by the by-standers, who drag him out of the ring by the heels, brandishing their knives about him; and having gone through the motions of skinning and cutting him up, they let him off, and his place is at once supplied by another, who dances into the ring with his mask on; and by this taking of places, the scene is easily kept up night and day.

That dancing with an animal mask is an old, old custom is shown by certain

Figure 55
Two devil dancers wearing characteristic masks. Each mask is standardized as to features and represents a particular evil spirit of which there are a large number in Tibetan mythology.

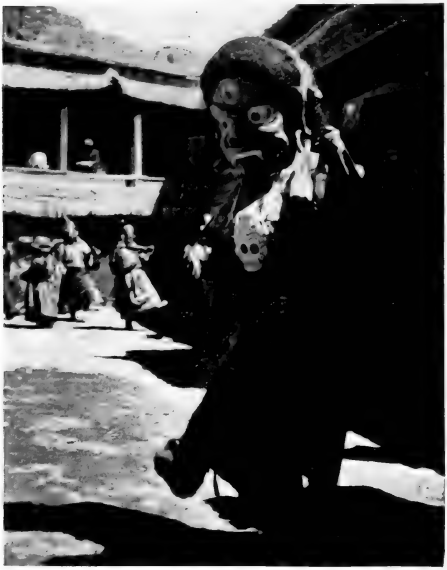

Figure 56
A dancing, masked figure—Tibet.

and the stooping, are all conceived to be representative of the leading animal or hero. A particularly forcible illustration of this is to be seen in the Eagle Dance of our Southwestern Indians as, covered with down like an eaglet and with rows of feathers down the arms and a tuft for a tail, the dancers, in stooping position, simulate the soaring of the eagle.

Assuming that these masks originally developed from a simple beginning, we may properly ask as to the nature of that simple first step. However, while everyone is interested in the origins of human customs, such origins are so elusive that many serious-minded students of the subject are inclined to doubt the possibility of finding them. Thus it has been proposed that masks were first the heads of animals; again, a device for frightening children, an outgrowth of designs upon shields, painted designs upon the face, etc. All of these guesses are plausible, but as no record of the beginnings of the mask have come down to us, there seems little hope of finding the truth about the matter. We can, however, conclude that it is an old custom, known in some form to most peoples.

Yet, though we may never be sure of how masks came to be so widely used, it is not difficult to see that they offer a medium for art expression. We have referred to the Indians of Alaska, experienced carvers of wood, who have produced a number of masterpieces, many of which, though usually grotesque, are

Stone Age pictures upon the walls of caves in France. One of these shows a dancer wearing the skin and head of a deer, while in another cave are three dancers in a row, with heads and skins of chamois, or similar animals. These last seem to be dancing by jumping up and down, holding the feet together, as do the native women in Australia when imitating the kangaroo.

As a rule, the steps in these dances are simple, but body movements are emphasized. The dancer is not merely enjoying the rhythm and excitement of the procedure, but may well be dancing as the impersonator of the animal or hero figuring in the ritual of the occasion. The swaying movements, the strutting

Figure 57
A pottery vessel from Mexico, which apparently represents a large mask headdress.

highly realistic. But for richness in conception and wealth of detail nothing seems to surpass the turquoise mosaic masks of the Aztec, in which the whole surface of the wooden mask base is overlaid with designs built up from minute bits of turquoise and other colored materials. That the earlier Maya used equally fine masks is shown by their low relief sculptures in which warriors and priests stand forth in masks and plumes. (Fig. 52) Not infrequently the sculptor, in presenting a profile, shows the face of the wearer behind the mask. If the reader imagines the great ruined Aztec temples, topping pyramids in their original grandeur, with highly decorative serpent columns, with brilliant wall paintings representing processions of plumed warriors and priests, and then in imagination tries to see the priests officiating at the altar, wearing masks encrusted with turquoise and topped by rich plumes, he will have some idea of the artistic heights to which the mask and the staging of rituals were carried in prehistoric America.

If we turn to the Old World, the paintings upon the walls of temples and tombs in Egypt present priests masked to represent the gods of that religion; further, the temples of India and China present many masked images. (Fig. 55) The reader interested in the artistic aspect of masks and their relation to the theater should look up that interesting book by Kenneth MacGowan, *Masks and Demons*, in which are many good illustrations of masks, with descriptive notes.

Turning now to more prosaic problems

(Continued on page 29)

Figure 58
PORTRAIT MASK IN STONE, VERA CRUZ, MEXICO

in the use of masks by the aboriginal Indian population, some curious facts in their geographical distribution are noted. Among the Indians east of the Mississippi River and near Hudson Bay, the Iroquois were not the only ones who specialized in masks. Some use of them was made by the Cherokee, Delaware, Nanticoke, Ojibway, and Choctaw, and probably by many others. West of the Mississippi, among the Indians of the Plains, the heads of the buffalo, the bear, and other animals were sometimes worn in appropriate ceremonies, but carved masks have not been reported. (Fig. 60)

On the other hand, the western belt of high land from the Arctic to Panama is conspicuous for the use of masks. As we have stated, the practice was highly developed in Mexico and Central America, and again among the Indians of lower Alaska and the coast down to the Columbia River. Even the Eskimo of Alaska, and as far east as Hudson Bay, made use of masks. (Fig. 40)

Turning back to California, we find almost no masks, but among the Indians of Arizona and New Mexico again the custom comes to the fore, the best known masks being those worn in the kachina ceremonies. (Fig. 32)

In South America, there were several highly developed civilizations in the Andean highlands, the best known being that of the Inca in Peru. There is good reason to believe that the Peruvians used masks, but these do not occur in collections; nevertheless, upon pottery, and occasionally in textiles, we observe what are certainly masks, some elaborate and some grotesque. The descendants of the Peruvians even now appear on certain Christian festival days in masquerade costumes that seem to be pagan. Of special interest, however, is the placing of masks upon the faces of the dead, not only in Peru, but in the whole of the Andean highland region from the Isthmus of Panama to northern Chile. Museum visitors are no doubt familiar with the mummy bundles from Peru, with their quaint wooden and woven faces.

Leaving the Andean highlands and turning to the lowlands of Brazil, we meet with many reports of masked dancers. The shapes are usually those of the jaguar, alligator, tapir, birds, insects, etc. In some cases wooden masks

Figure 59
A masked dancer from Vancouver Island, British Columbia.

Figure 60

The Assiniboin Indians still practise a ceremony known as the Fools' Dance. As may be expected, those who take part in this ceremony are given to clownish antics. One of the masks used in this dance is shown here. These masks are made of cloth.

are used, but usually they are of bark, are kept out of sight of women and children and, after the ceremony, are carefully burned. While data for many tribes in the lowlands of South America are lacking, yet, from what we have, it appears that dancing masks occur from Tierra del Fuego on the south to the Orinoco River on the north, but are infrequent in several parts of Argentine and Brazil.

It is difficult to summarize this distribution in a sentence, but the intensive use of masks is more frequent in the western highlands of the two Americas than in other sections.

The most elaborate and also the most artistic masks were, as may be expected, among the old native civilization of Peru in South America and of the Maya and the later Aztec in Mexico and Central America. Among the simplest and crudest were those of the Eskimo of the far north and of the Ona near Cape Horn at the lower end of South America. Thus, the Ona usually cover the head and face with a piece of rawhide upon which are painted a few spots in color to symbolize the spirit represented. One particular mask of this kind, according to the descriptions of observers, bore red and white spots, the emblem of the god of the heavens. Shifting to the far north the Eskimo around Hudson Bay use a few simple masks of skin, rather loosely fitted to the face and bearing simple markings.

We mention these outlying examples to emphasize the wide distribution of the masking idea. Also, wherever used, the mask is intended to represent a spirit, or a supernatural being, and is thus an aid to the impersonation of these mythological personages. The primary association of the mask is therefore with serious religious practices, rather than with entertainment and esthetic effects, suggesting that the masked dances and stage effects of civilized peoples also have a serious religious background.

In conclusion it appears that in human society it is the face that is important since there one reads the tensions and relaxations which reveal something of the motives and feelings within. Persons are distinguished by their faces chiefly, and it is upon the head and face that most of the efforts at make-up are

centered. It is not strange then that when primitive man wanted to pose as a god, he made a mask to show how tradition pictured that person; if a demon was to be represented an appropriate mask was constructed, etc., the mere wearing of which was sufficient to transform the human into the super-human. As masks were usually standardized the onlookers knew at once what personality was meant. This is the principle of certain ancient oriental theatres in which the actors changed their parts by taking up another mask, then the audience was given the cue to the change of personalities.

Figure 61
Masks of this kind are used in New Guinea as gable decorations on houses. They range from a foot to four feet in height and usually are mounted in pairs, one for each gable. They are brightly painted in red, white, and black and stand out vividly against the thatch of the roof.

The earliest known masks are shown in certain paleolithic cave paintings which are mute but effective witnesses to the knowledge and use of masks in that remote period of human evolution. Yet, since that time, how little we have changed! This very year masked gods will appear in the pueblo villages of our Southwest, and up in New York State, Iroquois Indians will appear in their terrifying wooden false faces to drive away disease. Face painting is simpler than the mask but often serves the same purpose, as when the Plains Indian, wishing to appear as a supernatural bear, makes black marks across his eyes and at the corners of his mouth. In fact all ceremonial face painting is designed with the same objective in mind as is symbolized in the mask, for when the appropriate symbols are made upon the face of the native he is to all intents and purposes the god or demon he impersonates. Impersonation is so basic in human behavior that even children spontaneously take it up. Possibly primitive face painting is older than the use of masks but both survive to this day.

Figure 62

An Australian native dressed for a ceremony. In this case the mask is built up on his own face, with plastic materials and down. However, it serves the purpose of a mask, the wearer impersonating one of the totemic gods. Arunta tribe.

Figure 63

This animal face has a movable lower jaw which the wearer manipulates by a string. It is a grotesque, but on the whole, a pleasing face, suggesting laughter. Vancouver Island, British Columbia.

THE ROAD TO MAN

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THE ROAD TO MAN

By ERICH M. SCHLAIKJER *Brooklyn College*

THAT man is the product of a continuous development from the earliest form of life that appeared eons of time ago, is by no means a new idea. This concept, with modification, was partly foreshadowed in the writings of some of the earliest naturalist-philosophers, and during the past one hundred and fifty years, many scientists in the biological, geological, and related fields have amassed a wealth of scientific data portraying with great accuracy the gradual transformation that has taken place from the earliest fish-like vertebrates to fishes, amphibians, reptiles, and to mammals leading eventually to man. Preëminent among the outstanding later contributors to the subject of man's place in relation to the lower vertebrates have been such men as Darwin, Haeckel and Huxley, and most notable at present is the work of Professor William King Gregory* whose many contributions, dealing with the stages of the evolution of man from the earliest fishes, are well known.

Likewise, the pictorial representation of stages in man's ancestry is not new. Several have done this, but they have not used as many forms and have employed, wholly or in part, living animals. The present attempt, however, is to portray, for the first time, a continuous series of restorations of thirty fossil forms in or near our ancestry from the earliest vertebrates of four hundred and fifty million years ago. These have been selected from the thousands of known fossil vertebrates because they best display the structural features necessary for giving rise to progressively higher forms, and have not been side-tracked by overspecialization from the road to man. It should be remembered that this road was a crowded one and that these chosen few represent only stages whose structural features characterize groups along the way. Evolution is not a matter of steps nor is it a condition of change from one individual to another. It is a slow transformation from lower to higher types—new groups gradually emerging from old ones.

When vertebrates appeared, more than three-fourths of the earth's history had passed. Since then, however, much has happened to the ever-changing features of the earth's crust, and there have been many marked environmental changes. The first vertebrates were fresh water forms of a time when there were no land plants, and the continents were transgressed by extensive seas. By the close of Devonian times there had been marked restriction of the seas, forests of spore-bearing plants covered the landscape, and the first amphibians appeared. They found the warm, humid climate of the Carboniferous Period, with its extensive, heavily forested swamp-lands most acceptable and they developed abundantly. One group took to the land and from them evolved the reptiles which were already flourishing at the end of the Paleozoic Era. This great Era was brought to a close by the Appalachian Revolution. Mountain systems were built up where once there had been seas and marsh lands; moisture-laden winds were cut off from regions that were once humid, turning them into deserts; and, this universal diastrophism had much to do with bringing about rather extensive glaciation. These changes lasted on into the early Mesozoic and had profound effects on the animals and plants of the times. Amphibians were restricted and many diverse reptilian forms had developed. The mammal-like forms eventually gave rise to the mammals, which soon were to become varied but were for the next 140 million years to occupy an inconspicuous place in a world of reptiles. Among the plants, cycads and conifers (pines, etc.) were now dominant.

By late Mesozoic times the seas were once more widely transgressing the continents. Extensive sections were turned into swamp-lands, and flowering plants were widespread and abundant. Another great revolution brought this Era to a close, and the effects on life were as striking as before. This really marked the dawn of modern life. Mammals were established and such plants as grasses, cereals, and fruits began to flourish.

As early as the Miocene Period, uplifting began again and culminated in the Ice Age. Coincident with these severe conditions was the change from the man-like apes into man, and it was during the critical times of the Pleistocene, when nearly one-sixth of the land surface was periodically covered with ice, that man fought his way to a higher evolutionary plane.

These are the main environmental changes, which during the last 450 million years, have marked the way of vertebrate evolution along the road to man.

* Cf. especially "The Origin and Evolution of Human Dentition," Williams and Wilkins, 1922, and "The New Anthropogeny: Twenty-five Stages of Vertebrate Evolution from Silurian Chordate to Man," Science 77: 29-40, 1933.

1

Man's oldest vertebrate ancestor, AS-TRA[illegible] ostracoderms [illegible] that had the front of the body [illegible] in plates of armor. Only the plate from delta deposits of fresh water origin at Canon City, Colorado, is known

2

Of wide distribution over Europe and North America [illegible] ostracoderms [illegible] ANGLASPIS (2). They have a single dorsal shield. Excellent preservation of some of these shields [illegible] network of sensory canals, gill

3

pouches, and even semicircular canals [illegible] first jawed relatives. The ANCESTRAL APHETOHYOIDS (3) form a shark-like group unique in having a hyoid gill slit that corresponds to our eustachean tube. They are for the

4

most part primitive and foreshadow [illegible] ray finned fish CHEIROLEPIS (4). This progressive type has started on the road to higher ray finned fishes, but has retained many structures especially in the dimensions and positions of the skull bones, of our

5

early lobe finned Devonian ancestors. The most primitive of these was OS-TEOLEPIS (5). Their lobe-like fins, fringed with dermal rays, were differentiated internally into elements that were to become the bones of our limbs. Nostrils opened into the roof of the

6

mouth showing the probable presence of lungs. One of the most advanced of these fresh-water, medium-sized, carnivorous forms was EUSTHENOPTERON (6) of Canada. He could paddle his way out of the water and was far on the way to be-

7

coming an amphibian. The early fish-like amphibians spent most of their life in water yet had many characters necessary for success on land. Such were the ICHTHYOSTEGALIANS (7) from East Greenland—the first tetrapods, or four-legged vertebrates. Bones between

8

the skull and shoulder covering the gills were lost and the first neck appeared. In the specialized yet primitive EOGY-RINUS (8) the shoulder-girdle is still attached to the skull. Having to hear through air, the first major step in the development of our refined hearing ap-

9

paratus was taken when the upper bony support of the old hyoid gill was transformed into a little bar (stapes) connecting the inner ear with an external drum. One group of amphibians, represented by DIPLOVERTEBRON (9) from the Carboniferous of Bohemia,

10

took to the land more and more, became lizard-like and had well developed limbs. Eventually they changed into reptiles—the next higher group of vertebrates. SEYMOURIA (10), the amphibian-reptile from Texas, shows this transformation—a change that meant,

11

among other things, a better developed brain, costal (rib) breathing, and that eggs could be laid on land. This change was the product of trying conditions at the close of the Paleozoic. ROMERIA (11), also from Texas, was a more advanced member of this stock. Known

12

only by the skull, this form seems to stand at the [illegible] that lead in one direction to many of the highly specialized and later reptiles, and in the other to CAPTORHINUS (12) and the mammal-like reptiles. This small form had rather slender limbs. The skull had

13

most of the primitive elements but the teeth were [illegible] possibly for eating molluscs along the shores of Permian [illegible] More advanced, however, was MYCTEROSAURUS (13), which belonged to an order of the more common Texas Permian reptiles.

14

Characterized by its large eyes, and [illegible] many of the features of the mammal-like cynodont (dog-toothed) reptiles of South Africa. CYNOGNATHUS (14), the dog-jawed reptile, has progressed towards the mammals in such

15

features as teeth, two of the posterior jaw [illegible] limbs under the body, and a shoulder girdle that closely resembles and has the same elements as the egg-laying mammals of today. TRINAXODON (15) was even a more mammal-like cynodont

NATURAL HISTORY MAGAZINE, By ERICH M. SCHLAIKJER
Drawn by GEORGE F. MASON
OCTOBER 1938

The transition from reptile to mammal was [illegible] DOS[illegible] Africa [illegible] still [illegible] the [illegible] han[illegible]

16

nearly joined the skull. When this hap[illegible] WEALTHERIUM [illegible]

17

the Pantotheria (all mammal), an or[illegible] ADVANCED PANTOTHERES [illegible]

18

jaws of *Melanodon* and others of these [illegible] best known [illegible] the later Cretaceous [illegible] DELTATHERIDIUM [illegible]

19

whose restoration is based on two skulls, [illegible] typifies the ancestor of a [illegible] line that gave rise to our first [illegible] We know this INSECTIVORE PRIMATE (20) stage [illegible]

20

jaws, and especially by their very primitive living descendants, the tree shrews of the Far East. ANCESTRAL LEMUROIDS (21) were the first true primates. Their remains are found in early Paleocene rocks in the Rocky Mountain States. Though specialized they reveal

21

many of the structures and habits of the lemur ancestry portraying in general our earliest primate tree-living ancestors. By Eocene times true lemurs were well established in the Old and New Worlds. PELYCODUS (22) was a small primitive form with teeth that re-

22

call an early lemuroid ancestry. More progressive was the American *Notharctus*. PARAPITHECUS (23) of the Oligocene of Egypt had advanced more in the direction of the ancestral anthropoids possessing the features of the teeth necessary for giving rise to monkeys

23

and apes. Egypt was also the home of the earliest known ape. From deposits there a single lower jaw named PRO-PLIOPITHECUS (24) has been described. Its form and tooth characters show that this progenitor of ours was decidedly like living apes though far

24

more primitive, as are all ancestral forms. More ape-like yet more primitive than any of the chimpanzee-gorilla group was DRYOPITHECUS (25). Fragmentary remains of this stock have been recovered [illegible] parts of Western Europe and India. [illegible] these

25

display, especially in the form of the teeth and in the number and arrangement of the tooth cusps, an ancestral stage common to the orang, gorilla, chimpanzee, and to man. AUSTRALOPITHECUS (26) of the Pleistocene of South Africa combined in a

26

unique way ape-like and man-like characters. It was a structural connecting link between the two families. The oldest and most primitive of fossil man is the Peking SINANTHROPUS (27). Several skulls, [illegible] teeth, skeletal fragments, stone implements, and charcoal

27

unearthed in an early Ice-Age cave deposit tell the story of this cannibalistic [illegible] Towards the close of [illegible] Period *Homo sapiens*, the species to which we belong, had appeared. [illegible] the WADJAK MAN (28) of Java. In

28

his many primitive skull characters, this lantern-jawed individual closely resembles the [illegible] the ancestor of all [illegible] including the advanced CRO-MAGNON MAN (29). [illegible] primitive features [illegible]

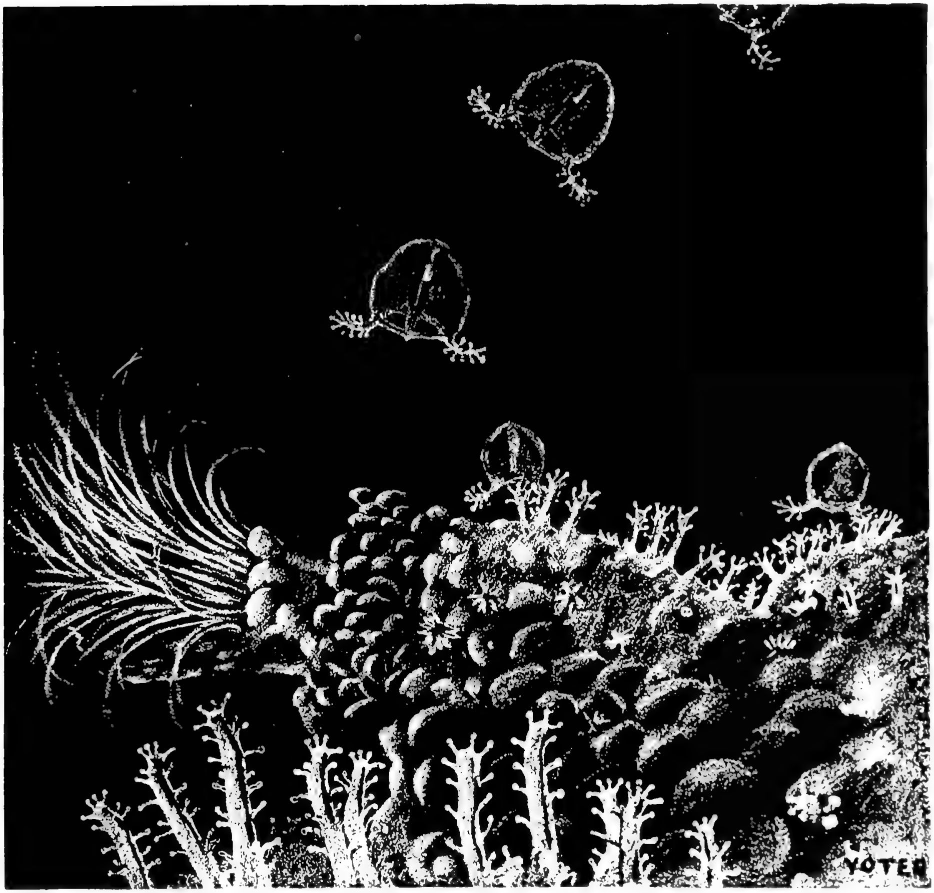
29

brain volume, averaged six feet tall and had a high degree of artistic ability as is shown by [illegible] This European [illegible] contemporaneous with the [illegible] pre-Recent glacial [illegible] been ancestral to [illegible] the white race of HOMO SAPIENS (30) of today.

30

FRAGILE CREATURES OF THE DEEP

BY ROY W. MINER



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FRAGILE CREATURES OF THE DEEP

By

ROY WALDO MINER

Curator of Living Invertebrates, American Museum of Natural History

GUIDE LEAFLET SERIES

of

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No. 98

[illegible] *model of the original scallop-* [illegible] *on exhibition in the* [illegible] *Museum. The inset in the* [illegible] *natural size of the shell.* [illegible] (Hydroides dianthus) [illegible] *a series of coiling limestone tubes from which the heads of the worms have extended their flower-like circlets of breathing-plumes varying in color from bright orange and white to pink, blue and gray. Covering these tubes are colonies of moss-animals, hydroids and protozoa as shown in greater detail in Figure 2*

FRAGILE CREATURES OF THE DEEP—*The story of the hydroids and their kind, whose schemes for coöperative social organization, specialized labor, and collective security set a Utopian example man would find hard to equal*

By Roy Waldo Miner
Curator of Living Invertebrates, American Museum of Natural History

A dead scallop-shell lodged between two stones in the swift current attracted my attention. It was covered over with irregular growths of a reddish color, with dots of blue and orange scattered here and there. I reached down to dislodge it from its anchorage in the tidal stream, placed it in a glass jar of sea-water partly filled with other specimens, and brought it back with me to the laboratory.

The scallop-shell was then transferred to a glass dish beneath a stream of gently running sea-water, and some time later I examined it under the low power of a binocular microscope. Immediately I was held spellbound, transported into a world of delicate beauty. My dead shell had sprung to life!

A colony of serpulid seaworms *(Hydroides dianthus)* had built their tiny limestone tubes in a coiled cluster over the fluted scallop-shell, each with a little round opening at the end about an eighth of an inch in diameter but magnified by my instrument to a sizable cavern *(Figure 1, opposite)*. Feathery tufts of orange, purple, and rose slid into view from each opening and expanded into petal-like crowns of gorgeous plumes, flaunting bands of crimson, blue and gold, set off by translucent collars of green and yellow.

The terminal portions of the tubes projected from beneath a brick-red calcareous crust, which completely covered the intertwined coils of the stony dwellings. This crust resolved itself into thousands of tiny vases with perforated walls. From the mouth of each vase a graceful, golden lily-like head protruded *(Figure 2)*. I recognized a species of moss-animal or sea-mat *(Schizoporella unicornis)*, so-called because of its spreading habit. Within my field of view thousands of these little creatures reared their delicate heads in regular ranks and as a shadow passed above them instantaneously disappeared within their shells. Soon they slowly emerged, unfolding their circlets covered with moving hairs to ensnare still tinier creatures and engulf them within their gaping central mouths.

This microcosmic world was so complex, and each detail so interesting, that only after an interval did I perceive hundreds of other fairy creatures standing erect between the shells of the moss-animals. Some were club-shaped, being expanded at the top, and all were translucent, disclosing within their elongate bodies an interior lining of rose-color. Their sides were adorned with stiff, outstanding tentacles, each terminating in a ball-like knob. As I watched, a tiny protozoan came blundering through the forest of fingers. It touched one of the knobs and after a twitch or two, suddenly ceased to move. It had been stung to death by the battery of sting-cells with which each knob was equipped and soon was drawn into the mouth which now expanded to receive it.

These creatures, of such fragile beauty, apparently so innocent, are in reality voracious hydroids of the species *Zanclea gemmosa*, extending their death-dealing weapons in all directions to slay small swimming animals that may come in contact with them. As I gazed through their crowded ranks, I noticed that many had a small ball-like projection on one side. In others, this had grown to a considerable size and was becoming indented to resemble a saucer. In one individual directly beneath my eye, the saucer had expanded to a transparent bell with a tiny clapper hanging down within it. Tentacles with knobbed branches extended in opposite directions from the margin of the bell. As I watched, the stem by which it was attached narrowed to a tenuous thread. Suddenly, struggling with vigorous spasmodic contractions and expansions of its transparent umbrella, it gave a quick pull, separated from the parent stem, and swam off to lead an independent life as a tiny medusa or jelly-fish *(Figure 3)*.

The hydroid polyps are among the simplest forms of animal life, and represent the stock from which

Fig. 2

all higher groups sprang. They are one grade above the Protozoa, the bodies of which are composed of but a single cell or particle of protoplasm, the basic living substance.

The hydroids also at the beginning of their life-history, start out from a single-celled egg, comparable to a protozoan, but they then go through a process of cell-division which results, first, in a mulberry-like cluster of cells; second, a stage in which these form a single layer of cells arranged like a hollow ball; and, third, the final essential phase, in which some of the cells push inward and line the cavity with a second but internal layer. The forming of this layer is shown in Figure 4, a-c. The embryo then elongates to form a tube *(4d)*, which attaches itself *(4e)*. A circular mouth appears at one end, around which a series of hollow arms or tentacles develops, and thus the adult polyp is produced*(4f, g)*. The cells of the layer lining the cavity of the tube remain large and secrete digestive ferments, while the outer layer becomes composed of smaller cells which are compact for protection, and sensitive so as to react to impulses from the environment.

Some of the cells, located in the tentacles, are unusually sensitive, and become quite complex, forming thread-cells. These are bulb-like and contain a turgid fluid, within which a delicate hollow

A populous community of hydroids, moss-animals and protozoa has covered the worm-tubes on our scallop-shell.

The hydroids (Zanclea gemmosa, *Inset A*), *project between the crowded moss-animal shells* (Schizoporella unicornis, *Inset C*). *Forked lappets of the swallow-tail Protozoan* (Folliculina hirundo, *Inset B*) *show between*

Figure 4. *Free-swimming embryo of hydroid. Formation of inner layer, cells produced from outer layer pushing inward to fill cavity* (a and b), *and splitting apart to produce a two layered embryo* (c),*which elongates to form a*

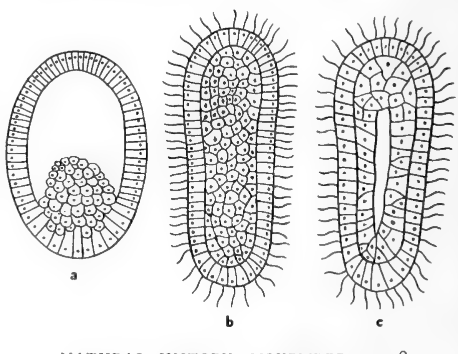
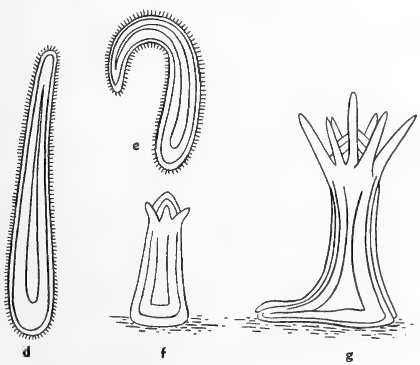


Fig. 3

Above, at left: the head of the sand-mason worm projects from its home of cemented sand-grains. To the right small medusae with bubble-like umbrellas are seen newly budded from their stationary hydroid-parents to form a free-swimming generation. They, in turn, hatch larvae to produce stationary hydroids.

free-swimming planula (d). *This soon settles down* (e), *its blunt end resting on sea-bottom and flattening, while mouth and tentacles appear at free end* (f, g)



thread is coiled like a lasso. Sharp chitinous pieces are contained within the blind terminal cavity of this thread. Projecting outside the cell are one or more sensitive hairs, the cnidocils, or triggers. When some creature comes in contact with them, the thread-cell contracts, squeezing the turgid fluid, which shoots out the coiled thread, turning it inside out with considerable force, so that the sharp chitinous pieces come together to form a barbed point. This penetrates the intruder, injecting at the same time a paralyzing poison. The thread-cells, or, as they are also called, lasso-cells, are very minute, but multitudes of them are shot out to take effect at the same time. The prey is therefore killed or stupefied and is drawn by the tentacles into the mouth so that the creature is soon engulfed within the cavity of the hydroid and digested.

Fundamentally the hydroid structure forms the basis of the evolution of the higher phyla. In fact, all higher animals culminating in man go through what essentially may be termed a "hydroid stage" in their development. That is, from a single-celled egg, they pass through cell-divisions which are more or less comparable with those of the hydroid; namely, a *morula* or "mulberry stage"; a *blastula* or single-layered "hollow-ball stage," and a *gastrula* or double-layered "hydroid stage." Likewise, in all higher animal forms, from the outer protective and

sensitive layer of cells of this latter stage (the ectoderm) are derived the skin and all protective structures, as well as the brain and various complications of the nervous system. From the inner layer, or endoderm, are derived the digestive system and all contributing glands; and also, through the intermedium of cells or out-buddings of tissues from this inner layer, are formed the body-cavity linings, blood-vessels, connective tissues, inner skeletal structures, reproductive organs and certain parts of the excretory systems of higher animals. So, back in the early history of the earth, the lowly hydroid polyp and its relatives, laid the foundation of higher animal evolution. Fortunately, members of the group have been preserved to us relatively unchanged, as well as groups representing various stages in realizing the possibilities of the hydroids' pioneer work, and these have formed the great animal phyla now existing on the earth.

The hydroids, and their relatives, the jelly-fishes, sea-anemones, corals, gorgonians, sea-pens and the like are comprised within the phylum Coelentera, which includes the animals in which the entire interior of the body acts as a digestive cavity. The Hydromedusae comprise that part of the phylum which centers around the hydroids and many of the jelly-fishes as well as those marvelous floating colonial creatures, the Portuguese Man-of-War, Porpita, Velella, and their relatives. As these form a remarkable series of unusual structures and adaptations, it is planned in this article to describe some of the outstanding species and their habits.

The simplest member of the hydroid group is the fresh-water hydra (e.g., *Hydra fusca)*, illustrated in

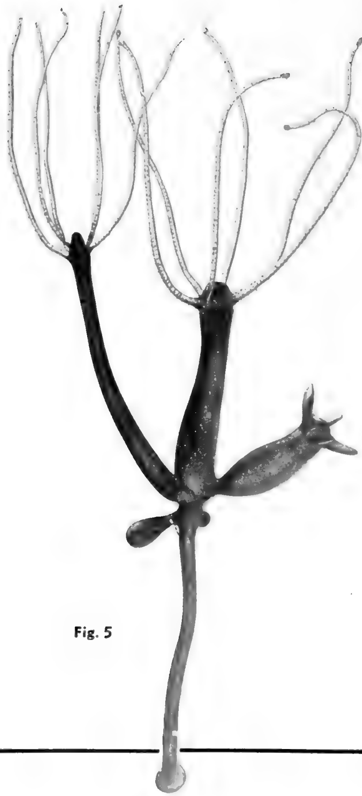


Fig. 5

(Above) *The Fresh Water Hydra is one of the simplest of all the many-celled animals. The inch-long body is a double-layered tube. A terminal mouth is surrounded by stinging tentacles which slay small aquatic creatures to be digested within the tube. The young are budded off and separate from the parent to lead an independent life.* (Model in Darwin Hall)

(Right) *Glass model of a typical marine hydroid medusa* (Syndictyon angulatum) *related to those in Figure 3. Note the transparent umbrella, within which hangs the tubular stomach with terminal mouth. Each of the four tentacles has an eye-spot at its base.*

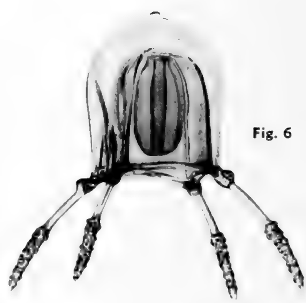


Fig. 6

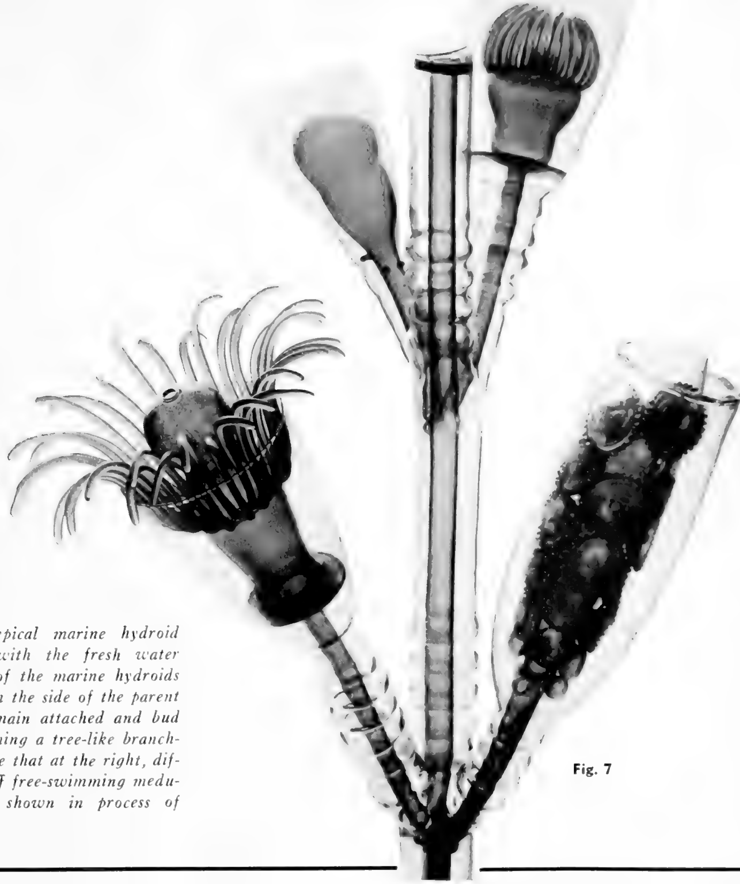


Figure 7. *Model of a typical marine hydroid* (Obelia) *for comparison with the fresh water Hydra* (Figure 5). *Many of the marine hydroids bud off new individuals from the side of the parent but, unlike* Hydra, *they remain attached and bud off others in turn, thus forming a tree-like branching colony. Certain buds, like that at the right, differ from the rest, and bud off free-swimming medusae, several of which are shown in process of development*

Figure 5. This little creature, an inch or less in length, lives in fresh-water ponds, and is often found in balanced aquaria. It is a simple hollow tube, brown in color, which stands on a disk-like base and stretches out its tiny thread-like cylinder of a body into the water. The terminal mouth is at the summit of a cone-shaped projection, the hypostome, and is surrounded by a circlet of six or seven long, filamentary tentacles plentifully armed with sting-cells.

It captures fish fry, worms, and small crustacea for food, moving about from place to place, either slowly creeping upon its disk-like attachment or, more rapidly, by a series of "hand-springs." That is, it bends its body over in a loop, takes hold of the bottom with its tentacles, and deliberately stands on its head to turn a somersault. Then the process is repeated.

It reproduces by budding a young hydra from its side, which remains attached for a time and then separates to lead an independent existence. It also reproduces sexually, developing sperms between the two cell-layers in the forward part of the body, while ovaries are formed in the lower part, the eggs being fertilized *in situ* in the same or in different individuals. An egg with a sticky envelope is laid, from which a young hydra is directly hatched. No medusa or jelly-fish stage is produced.

Our marine hydroids of the dead scallop shell *(Zanclea gemmosa)* attain the next stage in advancement. The hydroid polyps are budded off from a horizontal branching stem, or hydrorhiza, which weaves its way around and among the moss-animal shells. They do not separate from this stem, thus forming a connected colony, which continually spreads by budding off new individuals asexually. As

already described, these polyps, in turn, bud off free-swimming medusae, as the hydroid jelly-fish stage is called. They are like transparent umbrellas *(see Figures 3 and 6)*, with a little horizontal shelf or velum surrounding the bell-opening, while the mouth is at the end of the hollow tubular stomach (manubrium) hanging down like a clapper inside the bell.

There are four canals radiating from the stomach in the substance of the bell to connect with a marginal canal around the rim. The young medusa has two tentacles armed with sting-cells, while there are usually four in the adult. In the latter stage, the walls of the manubrium are swollen by the developing gonads or sex-cells. The fertilized eggs give rise to free-swimming larvae, which settle down on the bottom and grow to form new hydroid colonies.

This method of reproduction is known as alternation of generations, and often occurs in this phylum (e.g., *Obelia, Figure 7*). Thus, a hydroid grows from the larva and buds off other individuals asexually, which remain connected with it. This asexual hydroid generation gives rise by budding to a free-swimming medusa generation which, in turn, produces free-swimming larvae by sexual fertilization. These larvae give rise to a new asexual hydroid generation, thus completing the cycle.

In *Zanclea* the hydroids in the community are all of the same kind. However, if, when collecting in shallow water, one watches the smaller hermit crabs, *Eupagurus longicarpus,* the shells of certain individuals will be seen to have reddish velvety covering *(see Figure 8)*. If such a crab is placed, shell and all, under the dissecting microscope in a dish of sea-water, this will blossom forth into a remarkable colony of hydroid individuals, represented in Figure 9. This species *(Hydractinia echinata)* penetrates the shell-substance to form a network of tubes connecting the members of the colony with each other. The community includes three different kinds of polyp, each specialized for a definite function. The first are the feeding-polyps, with club-shaped bodies and terminal mouths surrounded by a single ring of tentacles. These capture the prey, swallow it, and proceed to digest it for the benefit of the entire community, passing it along through the system of underground tubes.

This is just as well, for the other two kinds of polyps possess no mouths or tentacles and are, therefore, dependent on the feeding polyps. The second series is specialized as reproductive polyps, bearing around their bodies grape-like clusters of medusa-buds. These never develop into free-swimming medusae like those of *Zanclea,* but remain attached, in partially developed condition. Ova and sperm are produced, however, and the former are fertilized *in situ,* giving rise to larvae from which new polyps are directly developed.

The third kind of polyp is the fighting or defensive polyp. It occurs abundantly along the edge of the snail-shell and around the margins of the colony. The individuals are long and slender. Their summits are equipped with spherical batteries of powerful sting-cells. These three kinds of polyps act together for the common good and also form a

Fig. 8

Figure 8. *Two specimens of hermit crab* (Eupagurus longicarpus) *with a smaller individual "stealing a ride," photographed from life. Note the velvety surface on the shells of the larger crabs caused by colonies of the marine hydroid,* Hydractinia echinata, *which completely cover it. This hydroid colony comprises hundreds of individuals connected by a network of tubules penetrating the substance of the shell. Figure 9 shows a portion of this colony greatly magnified*

partnership of mutual benefit with the hermit crab which wears them on its shell. The crab transports them from place to place, thus bringing them to new feeding grounds, where they profit by the minute creatures swimming in the water. The crab also tears to pieces larger prey, the fragments of which float up to form part of the food of the hydractinian colony. On the other hand, the fighting polyps not only act as defenders for their own community but also for the crab itself, because they aid in slaying the creatures on which it feeds.

Thus, two principles are introduced into the hydroid world. The first of these, polymorphism, involves the production within the same colony of different types of individuals specialized for different purposes but working for the common good of the colony on a coöperative basis. This is so successful among the lower organisms that we shall find in the floating colonies of the siphonophores it has been elaborated to a remarkable degree. If mankind were as successful in his coöperative schemes, we should have no difficulty in establishing an ideal Utopian form of government. Perhaps the lowly forms of life are more perfectly constituted for altruism.

The other principle referred to is that of copartnership with other unrelated species as, for example, the *Hydractinia* and hermit crab from such diverse groups as the Coelentera and Crustacea respectively. This phenomenon is usually referred to as commensalism, when the partnership involves sharing the same food.

Fig. 10

Figure 10. *A solitary marine hydroid* (Tubularia harrimani). *It does not bud to form colonies. Instead medusa-buds are produced which remain attached in bunches. They give rise sexually to fertilized eggs from which hatch free-swimming larvae to develop into new hydroids* (From Glass Model)

Figure 9. *Model showing section of hermit-crab shell* (see Figure 8) *greatly enlarged to show the specialized individuals making up the colony of* Hydractinia *growing on the shell. Three varieties of hydroid polyp are shown—feeding polyps, fighting polyps, and reproductive polyps. (See text for details)*

Fig. 9

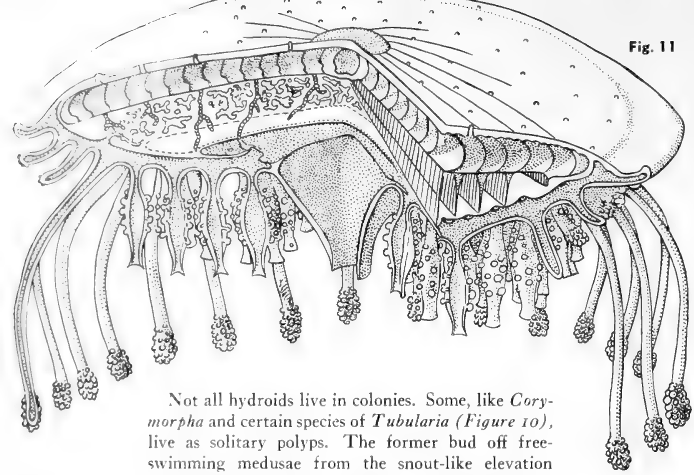


Fig. 11

Figure 11. *Diagram showing structure of the siphonophore,* Porpita (modified from Delage and Herouard). *This is a floating colony kept at the sea-surface by the complicated air-chambers of the central parent individual, the large mouth and stomach of which may be seen hanging down in the center. This is surrounded by several circlets of tube-shaped feeding individuals having mouths. Around the border of the colony are circlets of mouthless fighting polyps armed with sting-cells. The air-chambers are filled with a gas secreted by the parent polyp*

Not all hydroids live in colonies. Some, like *Corymorpha* and certain species of *Tubularia (Figure 10)*, live as solitary polyps. The former bud off free-swimming medusae from the snout-like elevation (manubrium) which terminates in the mouth. The latter produce medusa buds which never reach the stage of complete medusae and always remain attached. The *Corymorpha* medusae have beautifully delicate little umbrellas with a single tentacle attached. They give rise to sex-cells after becoming free-swimming. On the other hand, the *Tubularia* produce their sex-cells early and, as they are never free-swimming, they might almost be interpreted as sex-organs of the hydroid. It is thought by some that this is an initial evolutionary step toward the sex-organs of higher animals.

In other cases, like *Sarsia,* the medusa seems to acquire an unusual degree of importance, for after being detached from the hydroid instead of immediately producing eggs to be fertilized so as to develop a sexually formed larva, which in turn will become transformed into a hydroid, it starts budding off new medusae directly from its long pendent manubrium and these become free-swimming. So that a free-swimming medusa buds off free-swimming medusae directly. The latter, however, produce larvae sexually, and these become hydroids.

In some cases after such medusa buds reach a certain stage, they start to degenerate, losing their medusa-like organs, and finally become sporosacs, i.e., merely pear-shaped sacs from which ova and sperm are formed directly, the ultimate result paralleling the formation of similar gonads in hydroids. These are both instances in which the evenly developed alternation of generations becomes over-balanced in favor of either the hydroid or medusa generation, the alternating generation apparently becoming obliterated.

In some forms, as opposed to the condition in which the medusoid generation always remains attached to the hydroid, and is borne by it, there are certain species *(Phialidium)* in which the hydroid grows directly from the under side of the medusa-umbrella but always remains attached to it, being carried around by it from place to place. From this

Figure 12. *Model showing a colony of* Porpita *as it appears in life, slightly tilted to display the under surface. The colony is supported by a blue disk-shaped float about the size of a quarter, with the structure shown in Figure 11. The circlets of fighting polyps radiating from the margin have knob-like batteries of sting-cells at their extremities. Within may be seen the series of feeding polyps*

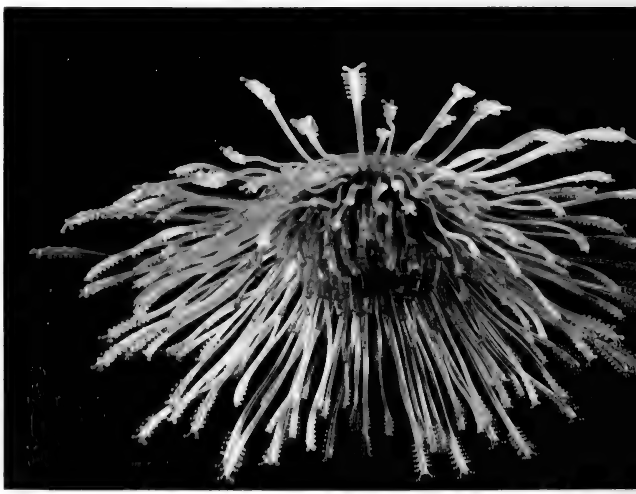


Fig. 12

passenger-hydroid, in turn, new medusae like its parent are budded asexually. So there are all possible stages grading from true alternation of generations in either direction, emphasizing the hydroid at the expense of the medusa, or the medusa at the expense of the hydroid.

On the medusoid side the ultimate result is found in the sub-family Trachylinae, consisting of beautiful medusae which have no hydroid stage whatsoever, giving rise to eggs which hatch out medusae like themselves without any intervening stage, with the result that alternation of generations is completely obliterated.

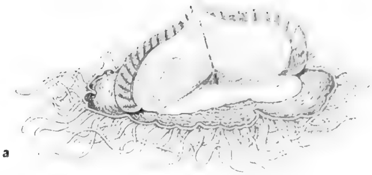
Perhaps the most remarkable specializations occur in that wonderful group of the Hydrozoa known as the Siphonophora. These are oceanic species that form floating and swimming colonies of many types of individuals specialized for diverse functions which operate for the common good. This reminds us of the feeding, fighting and reproductive individuals of the *Hydractinia* on the shell of the hermit crab, but in that case the members of the colony are anchored in the shell. The siphonophores, on the other hand, are floating colonies in which the members bud from an original floating mother-polyp that starts the colony. The best known of these floating cities are the Portuguese Man-of-War *(Physalia pelagica)* and its relatives *Velella* and *Porpita.*

Hundreds of other species belong to the group, comprising many diverse forms, involving so great a variety of complicated arrangements that it would be highly confusing to describe many of them, so our attention will be limited to a few of the most typical.

Imagine one of our medusae, as it swims about, acquiring a greatly expanded umbrella disk stiffened with concentric rows of air-chambers to aid in keeping it afloat, instead of depending on swimming by means of alternating pulsations of the disk. Suppose that circlets of polyps bud from the under side of the disk and hang down in ordered ranks arranged concentrically around the mouth and manubrium of the parent. This is the condition in the free-swimming hydroid colony known as *Porpita,* shown in Figures 11 and 12.

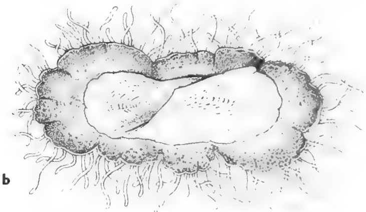
The multitudinous polyps hanging beneath it have assumed various differences in form and function. As shown in Figure 11 some look typically polyp-like, having tubular or rather vase-shaped bodies with circular terminal mouths, surrounding the larger central mouth of the medusa. Around the base of each polyp are medusa buds in various stages of maturity. These are, therefore, the feeding and reproductive individuals of the colony. Surrounding them, and extending far beyond the edges of the disk, are ranks and ranks of long, slender club-

Fig. 13



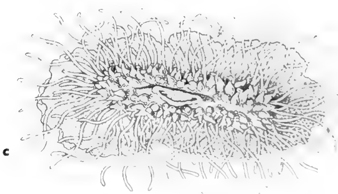
a

(Above) *Colony of* Velella *which resembles a small rectangular raft four or five inches in length. A peculiar sail-like structure is situated diagonally across the upper surface.* (These figures redrawn from Haeckel)



b

Upper surface of a colony showing the sail fore-shortened. The inner lighter portion is equipped with concentric air chambers. Fighting polyps project from underneath its border.



c

Under surface of the same colony showing the outer series of fighting polyps and the inner set of flask-shaped feeding polyps about the central slit-like mouth.

d

Vertical transverse section through the forward part of the float of Velella *showing the concentric air-chambers. Below are the various types of individuals described in the text. Reproductive gonads are visible around the bases of the feeding polyps*

shaped polyps, with no mouths, but fringed with tassel-like batteries of sting-cells. These are the fighting polyps, having for their sole duty the capture and slaying of prey to be turned over to the feeding polyps. It is obvious that the fighting polyps, having no mouths, must depend on their neighbors for food, which is passed to them predigested through the internal connections with the main colony. While the feeding-reproductive polyps also have sting-cells, they are not developed to the degree seen in the fighting polyps. The living *Porpita* floats and swims in great schools in the warm waters of the Gulf Stream. Each colony is a little blue disk about the size of a quarter. They are quite abundant in the open sea off the southern New England coast during the summer, especially after a southeast gale brings in spurs of the Gulf Stream.

Closely related to them is another colonial siphonophore, *Velella,* which resembles a small rectangular raft about four or five inches in length *(Figure 13).* Like *Porpita,* the raft is kept afloat by a series of concentric air-chambers, of which the inner part of the raft is constructed, while an upright crest or keel is set diagonally along the upper side of the float and apparently acts as a sail. From underneath the raft an assemblage of polyps similar to those of *Porpita* extend down into the water, including a central feeding mouth and manubrium, while around it are arranged multitudinous pendent feeding and reproductive polyps. As in *Porpita* a fringe of fighting polyps stretches out into the sea on all sides.

The most remarkable of all this strange group of siphonophores is the Portuguese Man-of-War *(Physalia pelagica),* illustrated in Figure 14. A fleet of graceful iridescent bubbles gay with intense scarlet, green and violet dances on the summer sea. But streaming far down below the surface long tentacles of blue, bordered with bead-like batteries of the most powerful sting-cells known to exist among sea-creatures, trail along like death-dealing dredges,

Fig. 14

Figure 14. *The Portuguese Man-of-War* (Physalia pelagica) *is the largest and most spectacular of the Siphonophores.*

A certain species of fish (Nomeus gronovii) *swims, immune, among its powerful stinging tentacles. (Life size glass model in American Museum)*

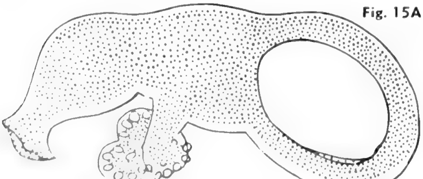


Fig. 15A

Figure 15A. *A newly hatched* Physalia *showing original [illegible] with open mouth and rear part of body secreting a [illegible] of gas. A single tentacle projects from below*

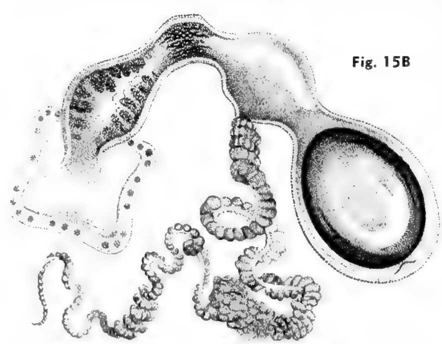


Fig. 15B

Figure 15B. *A later stage with expanded mouth, and longer and more fully developed stinging tentacle. The digestive cells show through the transparent walls of the tubular stomach*

slaying fish and all other organisms that come in contact with them. The prey adheres to the strands of this net and is drawn up by their shortening threads until it comes in contact with the hundreds of hungry mouths stretched out by the azure polyps hanging from the common float. Green finger-like polyps of great sensitivity feel over the prey and soon its juices are absorbed by the feeding polyps.

Hanging among the other individuals composing the myriad clusters of this floating colony are finely branched bunches of reproductive individuals like little pompons, salmon-pink or white in color. These are developing medusae of two sorts, male and female. The female medusae reach maturity with perfectly formed umbrellas and become detached to swim away to produce their ova. The male medusae at the base of the cluster remain attached and do not develop the umbrella structure.

It is hard to realize that these floating colonies are not single animals, so beautifully are the different sorts of polyps composing them coördinated in their functions and activities. They are, nevertheless, colonies or cities of individual polyps each of which has come into existence as a bud from a single original polyp which hatched from the egg to start the colony. In the case of the Portuguese Man-of-War, the original polyp is the float. In its earliest stages this was a typical hydroid with open mouth and tube-like body which was able to float at the sea-surface by secreting an internal gas, lighter than water, at the extremity of its sac-like body *(Figures 15a, b)*. Shortly thereafter, the parent polyp began to bud off additional polyps with feeding mouths along one side of its external surface *(Figure 15c)*. These remained attached, thus forming a colony. The parent's body then became greatly inflated with gas, thus acting as a float to support the growing community, while the functions of feeding and digesting were delegated to the rapidly multiplying young polyps *(Figure 15d)*.

The secretion of the gas increased as the colony grew larger, so that the supporting power of the float kept pace with the demands made upon it. With each feeding-polyp a fighting or stinging individual budded forth. Some of these remained short, while others, with their powerful bead-like batteries of sting-cells forming a close-set border along their entire margin, elongated to extend for down into the depths of the sea, alternately stretching out to their full length and contracting in tightening coils to bring the captured prey close up within reach of the now multitudinous greedy mouths *(See Figure 14)*. By the time the sensitive palpons or feeling polyps and the clusters of reproductive gonads had matured, the Portuguese Man-of-War colony had greatly increased in size and weight, but was always adequately supported by the enlarged float.

This latter is a remarkable structure of great beauty. It is essentially a large thin-walled sac, eight to ten inches in length in adult specimens. In some individuals, its thin, translucent walls are brilliantly colored, with rich crimson and intense violet hues blending into each other imperceptibly. Others grade from red to bright green. It is boat-shaped, with pointed prow and stern, and somewhat resembling a medieval caravel, while its thin walls are equipped with flat, transparent muscle bands the contractions of which continually cause it to change its shape.

A chambered crest adorns its summit and the protean changes of its outline enable it to trim sail and head into the wind.

Small fishes are stung to death and captured by its tentacles, with the exception of one species, seen in Figure 14, the Portuguese Man-of-War Fish *(Nomeus gronovii)*, which is apparently immune; for it swims freely among the deadly appendages without injury. This seems to be a commensal association of benefit to both organisms, for it is said that the fish acts as a lure, attracting other species

Figure 15C (Below) *As the colony grows, new polyps bud forth in clusters, each of which includes a feeding polyp, a feeling polyp, a reproductive polyp and a long fighting polyp or stinging tentacle*

Fig. 15C

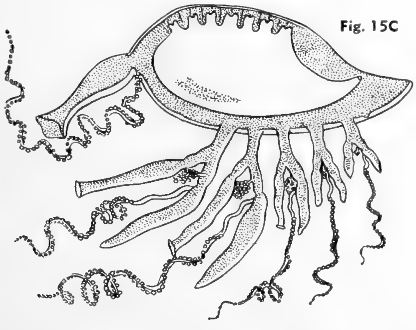


Fig. 15D

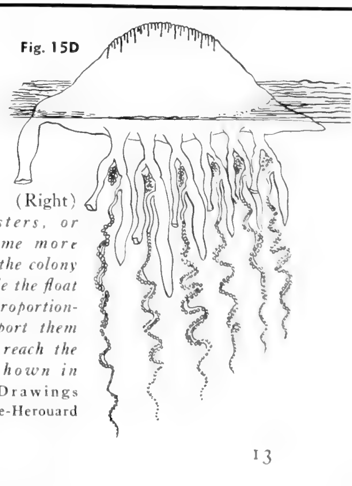


Figure 15D (Right) *These clusters, or corms, become more numerous as the colony matures, while the float increases proportionately to support them Finally they reach the condition shown in Figure 14* (Drawings after Delage-Herouard and Haeckel)

to their doom, while in turn it is sheltered from its enemies and perhaps shares the results of the capture.

In siphonophores like *Circalia stephanoma (Figure 16)* the float is reduced to a terminal bulb which barely keeps the colony at the surface of the ocean. This species, however, is equipped with an additional series of polyps, the swimming bells, which are umbrella-like structures surrounding the float in a circle. By their rhythmic contractions they assist in keeping the community at the surface and propel it through the water. A circle of feeling polyps projects just below the swimming-bells, overhanging clusters of male and female reproductive individuals. A single large feeding polyp hangs downward from the center, and interspersed among the other structures are numerous small stinging tentacles. The most important aggressive organ is a huge, branched, stinging tentacle that extends far downward from one side of the colony to trail its deadly nettle-cells far below. Other forms related to this, such as *Nectalia loligo (Figure 17)*, have a double vertical series of swimming-bells below the diminutive float, while a set of protective "bracts" or covers hangs down to protect the underlying organs.

Still other species, among the endless varieties of forms composing this protean group, are without floats and depend entirely on swimming-bells to keep their colonies near the surface. In some cases a single swimming individual is sufficient for this purpose (Monophyidae), as shown in Figures 19a and b, while others have two bells, one below the other (Diphyidae), Figures 19c and 20. These colonies trail the other component members behind them in successive clusters attached to a long filament like a tail.

Each cluster (cormidium) is composed of a protective bract enfolding the base of a small group of individuals, including a feeding polyp, a feeling polyp, reproductive gonads, and a long branched stinging tentacle. Some of these are developed to an enormous extent, forming complicated colonies of great delicacy and beauty.

In this remarkable group of the hydroids, based upon the plan of a simple tubular polyp, Nature has evolved an infinite variety of species of all gradations of complexity, and in the process has solved certain basic principles, such as colony formation, alternation of generations, division of labor among specialized individuals, and the coöperation of different species for mutual advantage. These achievements attained in this lowly group have made possible the development of important features of structure and function in the evolution of the higher groups in the animal kingdom.

Fig. 16

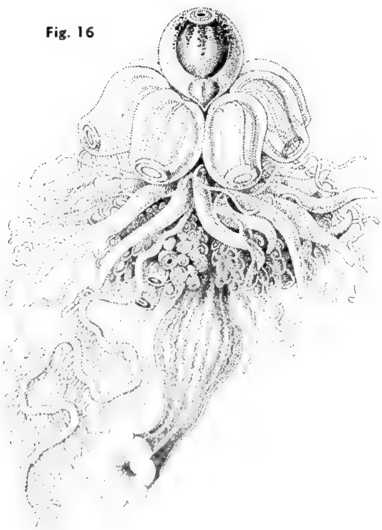


Fig. 17

Figure 16. *In* Circalia stephanoma *the float is much reduced, but the colony swims by means of contractile "swimming bells"* (Redrawn from Haeckel)

Figure 17. Nectalia loligo *shows the float further reduced, while the swimming bells are more developed* (Redrawn from Haeckel)

Figure 18. Athoria larvalis, *with diminutive float, has bracts terminating in swimming bells to support its colony clustered around the single large feeding polyp* (Redrawn from Haeckel)

Figure 19. *In* Sphaeronectes (*a*) *and* Ersaea (*b*) *the float has disappeared. They swim by means of a single powerful contractile bell.* Diphyes (*c*) *has two such bells* (Redrawn from Mayer)

Figure 20. Diphyopsis *with two bells trails a magnificent series of corms each bearing a set of specialized individuals* (Redrawn from Haeckel)

Fig. 18

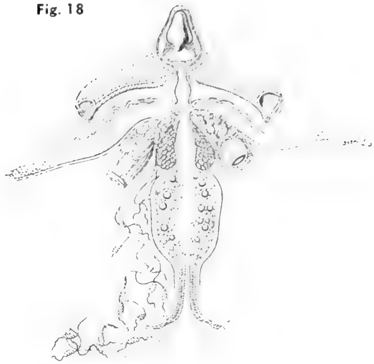


Fig. 19

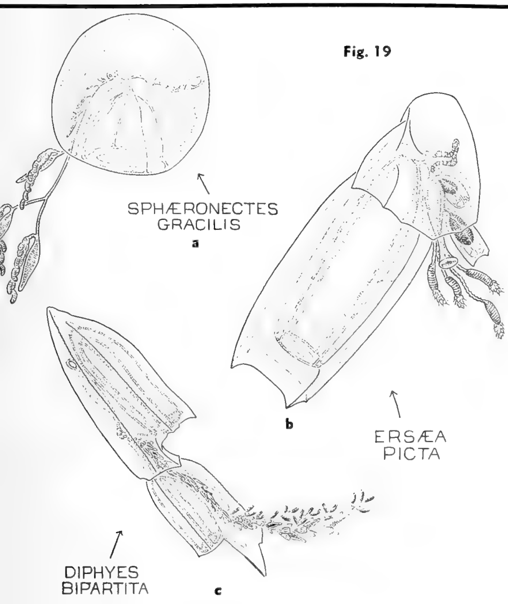
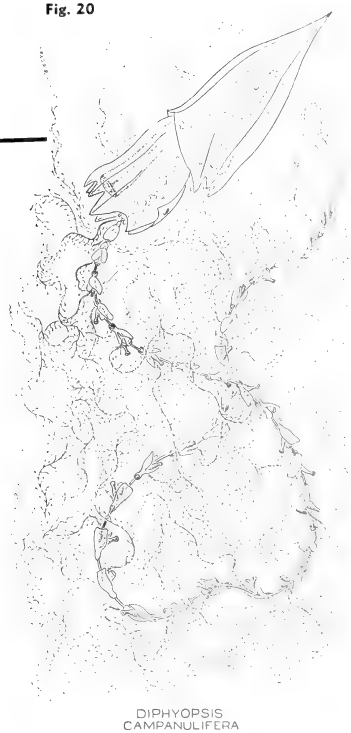


Fig. 20



MASTERPIECES OF PRIMITIVE SCULPTURE

By GEORGE C. VAILLANT

THE AMERICAN MUSEUM OF NATURAL HISTORY

MASTERPIECES OF PRIMITIVE SCULPTURE

By Their Arts You Shall Know Them

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BY THEIR ARTS
You Shall Know Them

AMNH Photo

1. TIGER-FACED deity mask (Olmec) from Central Vera Cruz

Whether it be fear of the supernatural typified in the eerie carvings of Polynesia, the gaudy ritual of fantastic New Guinea masks, the astonishingly modern impressionism wrought on an African elephant tusk, or the subtle naturalism of clay sculpture in ancient Mexico — each primitive art tells the essential story of the community that produced it

By GEORGE C. VAILLANT

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ART is a common denominator in all types of human culture. The greatest artistic achievements are still made by hand, so that the element of machinery, which so distinguishes modern Western Civilization no more affects the production of our modern arts, except perhaps architecture, than it does those of earlier eras. However, the social background of our modern art is very different from that of earlier and less complex tribes and nations. Whereas these simpler groups produced their arts in terms of craftsmanship, in our Western Civilization we confine such creative impulses to a small proportion of the population, whom, as "artists," we maintain as a special part of our social and economic structure.

Our attitude to our own artists is also affected by the extreme complication of our social organization. Simpler tribal communities often maintained skilled craftsmen by virtue of their artistic production, even as we do our own people with superior talents. On the other hand the universal primitive dependence on hand-work makes the cleavage between especial talent and ordinary skill seem less profound than in our modern communities.

The tendency of our artists and designers to draw inspiration from the arts of other peoples in other climes and other times may be due in part to this communal poverty in artistic expression and in part to the specialization implicit in a highly skilled profession. The fact that our modern use of the word "Art" has added to the term special shades of meaning not to be found in most languages may be also symptomatic of this general movement away from group participation in the creation of art forms.

Yet, if we moderns do not produce communal arts, we do show a wide interest in the achievements of other peoples, who have not lost their manual skill through complete dependence on machine production. Representative of this interest on our part is the art museum, an element of popular instruction and gratification, only recently introduced into our social economy. Here we may see sculpture, painting, and other works of art carefully selected according to our own ideal of beauty and the historical development of this ideal.

The art museums carefully distinguish the more modern works as to their creators, but they can only designate the period and place of origin of the earlier masterpieces. Moreover, this anonymous art of the past often has a religious or utilitarian purpose, whereas the most recent identified works seemed designed for purely aesthetic ends. The relationship of the ancient religious arts to our modern aestheticism can be readily seen, and from the point of view of appreciation or intrinsic worth, the past does not have to bow to the present.

The majority of the art museums, for reasons of public taste, space, and finance, direct their exhibits with a view to their realtionship to our present culture. There is a very obvious tendency to broaden the historical and comparative base of our modern art. Examples of Egyptian, Chinese and Cambodian art enhance and expand the view of aesthetic achievements of mankind. Yet there are many important and interesting schools of artistic expression that cannot be included in the museums primarily formed to show art.

These developments, however, are not inaccessible. They are collected and exhibited in anthropological museums, whose purpose is to show the Natural History of Man and whose exhibits are frequently combined with those of Natural Science, as in the American Museum of Natural History. Since anthropology occupies itself with the biological, social and technical

Photo by Hess

2. *(Left)* NOT A NIGHTMARE Buckingham Palace guardsman, but a New Ireland native's concept of a supernatural being. The (to us) repellent effect should be overlooked in favor of the skillful carving and the insight it gives us into this people's awe of powers of Nature

AMNH Photo by Kirschner

AMNH Photo by Kirschner

Photo by Hess

3. THE CLOSE ASSOCIATION between community attitude and the shape and matter of community art is shown in the examples above, left and right. Beneath the painted clay face *(top)* is a human skull used by the New Guinea artist as a manikin. Note weakness of chin due to discarding skull's lower jaw. Even more lugubrious is the Maori head-hunter's art *(left)*. Here is the ultimate in "naturalism." This human head solemnly and ingeniously preserved had the elaborate color design "chiseled" rather than tattooed into the skin during life. Both forms betray a realistic interest in The Head as against the bird-beaked figment of an Easter Islander's fancy *(right)* which suggests imaginative mysteries. All these forms are distinctly alien to the western mind

processes by which man has been able to live in every part of the globe, the art of man appears as an aspect of his general evolution, not as a subject in itself. By a sort of informal consent these collections stop with the dawn of civilization, whereupon the art museum takes up its phase of the story and the museums of science and industry or history display the other phases of cultural evolution.

It is obvious that this cleavage is artificial. There is much material of anthropological importance in a major art museum and many fine examples of art in a museum exhibiting the natural history of man. Yet, the difference in manner of display and emphasis tends to divide the two types of museums as well as the interests of their visitors. To reconcile this apparent divergence the American Museum of Natural History has set up an exhibition to stress the notable achievements of peoples whose arts were not tributary to the main stream of European civilization, and consequently are not represented in museums illustrating the art history of our culture.

Skill in depicting the human form and in suggesting its spiritual essence is an important index to the artistic achievement of mankind. Even as man originally created his gods in his own image and endowed them with his own attributes magnified and intensified, so in making images to revere and to symbolize, man tried to reproduce the human form. Thus in these outlying zones of human culture, sculpture becomes an excellent means for comparing the native arts with our own highly defined artistic conceptions. The formulae of presentation, the ultimate synthesis of the physical type, the hauntingly intangible reflections of the group psychology, all lead us into fascinating fields of contemplation. A study of pure design, if more directly comparable, is too cold to challenge the imagination as does sculpture. This point will become more clear when we consider the tribal carvings we have selected as illustrative of the high development of arts outside of our own tradition.

Easter Island

Isolated in the limitless expanses of the Pacific, Easter Island is the source of an important sculpture in wood and stone. The wood-carving combines three features, a religious purpose, a naturalistic presentation and a firmly established style. The figures represent either old men or elusive beings with heads of birds. They seem to be designed as portable idols, since they do not stand without support, and disclose the delicacy of detail and subtle gradation of surface planes requisite to an object designed for handling. In contrast to the wood-carving, the massive heads and torsos, made from huge blocks of lava ranging up to 30 feet tall, appear rude and uncouth, but symbolize, nonetheless, the power of the supernatural so dominant in primitive life.

We cannot recapture the precise attitude of mind of these carvers in wood and stone, since forcible removal of the population in 1862 destroyed the native culture. However, technically and stylistically Easter Island art fits into the general pattern of Polynesian sculpture. If the forms are perhaps ancient in concept, they are not of any tremendous antiquity. However, contemplation of these carvings from our own emotional and intellectual plane discloses an eerie quality, fitting to the religious art of a people isolated in the midst of a limitless sea.

New Guinea

In contrast to the austerity of Easter Island sculpture, the art of New Guinea discloses a barbaric panoply of ritual. Intricate design, bright colors, fantastic masks, complexly stylized idols, create a rich pageant to absorb the tribal interest. Ceremonies for initiates, ceremonies for uninitiates, ceremonies bought, and ceremonies sold, involved a mass participation in plastic and decorative expression, productive of an astounding array of highly decorated paraphernalia. While individual examples or even a large number of specimens, hastily seen, might well induce the effect of an exuberant lack of restraint, closer study reveals an adherence to stylistic canons and to forms of presentation, that indicate a long tradition of expression. In its broadest aspects this wood-carver's art radiates through the Melanesian islands, each of which has its distinctive tribal styles. Its past may extend even to the early culture of the Asiatic coast.

Such art as this is difficult to harmonize with our west European canons, but in a decorative sense, one could easily conceive how the very intricacy of a New Guinea carving would relieve the rigorously mathematical lines of our most modern interior decoration. Although we may reject these styles as bombastic and outside of our tradition, Melanesian art is a distinctive, expressive, and calculated result of centuries of practice under a well-defined, if unverbalized, æsthetic.

Utilization of Natural Forms

The direct principle of reproducing natural forms seems stifled in the midst of this rampant Negroid development of design. Yet the treatment of human skulls discloses a plastic sense that stands out from the rest of the art. The skulls were covered with clay, which was then carefully modeled with an accuracy suggestive of actual portraiture. The ultimate end may have been magical or ritualistic, but the result is a noteworthy sculpture. All too often, the skillful

building up of the features is lost through the application of paint, which, although reproducing the appearance of a living subject, nonetheless obscures the essential excellence of the modeling.

In contrast to this plastic art, based upon head-hunting, is the Maori custom of carving and dyeing beautiful designs upon their faces during life. After death the heads of notables were smoked and carefully preserved. The process brings out the design and shows how exquisitely the elements of the pattern were gauged to conform with the position of the features of each face.

Both of these methods of using the human head as a background for artistic expression far surpass a third variation found in the Amazon drainage of Ecuador and Peru. Here the head of a victim is skinned and the hide reduced by heating and drying. Manipulation of the skin retains the main contours of the face and the adornment of the head with colored feathers and insect wings discloses an interest in ornament. Yet the total result is crabbed and wizened, hardly to be compared with the superb techniques of the Pacific Islands.

West African Art

The art of Africa evokes from us moderns a more direct response than do these styles from the Pacific. African sculpture seems to express the lusty emotions of the Negro, and conforms to the sensory appeal of our European tradition. Perhaps because of its greater familiarity to us, perhaps because of its emotional content, African art does not have that strangeness of presentation and function that blocks our approach to many of these distant arts of obscure peoples. While all Negro carving has a generic resemblance from the point of view of Europe, familiarity with the subject will disclose many tribal and regional styles. In all of Africa, the west coast has produced the most exciting developments, the bronze art of the Benin region and the ivory sculpture of the Mangbetu people.

The Benin bronzes fulfilled the needs of church and state as did the medieval art of Europe. This strikingly rich fruition of Negro genius has a bold realism, fitting in those west coast kingdoms, where killing, cannibalism, polygamy, drunkenness, and, above all, pomp prevailed. The casting of the bronzes by the lost-wax process may have been introduced by Europeans, but the expression and the styles have no hint of influences alien to the Negro. The heavy pride to be seen in photographs of west coast kings is transposed to these bronzes and the accentuation of the wide, low, thick features reveals the artists' understanding of the way to visualize the essential character of the tribal psychology. As befits a national art, there is an inherent monumental quality indicative, not of the individual artist, but of the æsthetic influencing the whole tribe. The production of this tribal art was a craft, not an embodiment of an individual's perception, and we notice in the arts of the Middle Ages, although the traits stressed are less full-blooded than the African, the same obliteration of individual reaction in a great mass expression.

The Mangbetu ivory treasure is probably the last coördinated output of a West African kingdom. The firm hand of colonial administration plus the drying up of the ivory supply combine to extinguish the full development of a national art. The social background for the creation of this ivory sculpture was much the same as in Benin, but the gleaming white of the medium employed gives a less lowering effect than the blackened bronze of Benin. Elongated forms, controlled by the shape of the elephant tusks, have a gracility lacking in the bronzes. Ivory also provides a natural surface for drawing so that the graphic arts are represented in a lively and expressive manner, although less grounded in the traditional forms of the sculpture. In this Mangbetu art, craftsmen, working in a tradition, served religion and the coast and created a closely coördinated artistic expression that permeated a wide variety of forms. Even as the arts of the Middle Ages, this African æsthetic reveals unity but not repetitiousness in its richly varied application.

Occasionally, the element of pure realism breaks the bonds of custom and exquisite forms result. Two superb clay heads from the Yoruba country will rank with great portrait heads of any civilization. African art, because of its vitality, will stand high in the scale of tribal and national arts. Our familiarity with the racial types involved and our comprehension of Negro emotional values bridge the gap between African presentation and our own. Therefore, African art makes an excellent point of departure for the understanding of arts wherein a distinctive set of racial and emotional factors are involved.

New World Art

The art of the American Indians passes through the full range of artistic evolution. All stages are represented from the highly sophisticated products of highly ritualized civilizations to the crude linear patterns of people almost on the threshold of human living techniques. Yet this rich and complex field for observing not only the fulfillment but also the formation of artistic expression, is virtually unknown to the world of art. Three factors have been instrumental in barring a popular esteem for our aboriginal continental art: it is exhibited in the custody of an-

4. *(Left)* AFRICAN ART, with its many ardent devotees among us moderns is generally more appealing to our emotional temperament than the work of any other primitives. Somewhat paralleling our feelings about African as opposed to oriental music, it seems lustier, earthier, more stimulating than other more decorative arts. Down center of page are two items in a Mangbetu chief's royal treasury. Both are beautifully incised ivory pieces curiously possessing the abstraction of form sought in much modern sculpture. Upper figure is girdled with a kind of pictorial frieze, while the graceful taper of the lower one is controlled by the tusk's shape

Photos by Hess

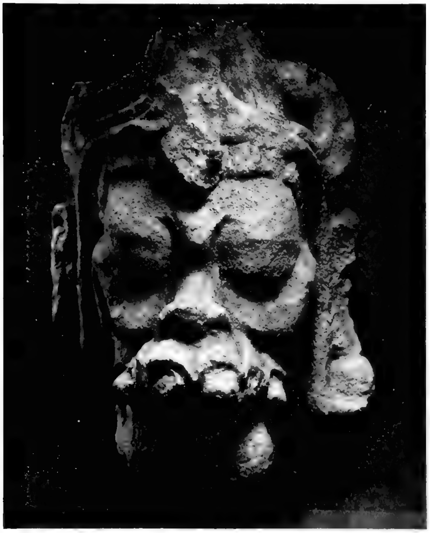
5. *(Below)* BENIN BRONZE is the alliterative catalogue name for this collector's piece and indicates the traditional medium of the Benin tribe of West Africa. With this alloy they fulfilled the needs of church and state much as did the art of medieval Europe. Students comparing the two also point out that both forms show the strict subordination of individual expression to that of the group, a quality our modern art has all but lost

AMNH Photo by Kirschner

6. *(Below)* SOMEWHAT MORE ELABORATE is this Congo-made head, a striking ornament attached to no more exalted a base than an ordinary clay pot. Notice the skillful execution of the features. This together with the care expended to work up a metallic surface sheen seems a prodigal waste of talent to us, accustomed as we are to machine produced utensils

AMNH Photo by Kirschner

7. *(Above)* An aboriginal "cherub"; typifying the highly humanized Totonac art of what is now the state of Vera Cruz (Mexico). Relics of pre-conquest days in this region often show a whimsical likeness to Chinese art, doubtless enhanced by the depiction of the Mongoloid features so common in American Indians. Humor, like that so clearly defined in this clay piece, is a rarity in New World art generally and seems restricted to this area. Though nearly as pleasing to the modern eye as African works, Middle American sculpture might be more esteemed were we not unfamiliar with baked clay as a medium for major works of art



AMNH Photos by Kirschner

8. *(Above)* Two Maya masterpieces which once looked down from the walls of a sacred temple. The symbolism of an established tribal ritual looms large in the one at left with its grotesque features, but the excellence of the naturalism in the other has the appeal of a great world art

9. *(Left)* This God's mask from the Tabasco region displays an unusually sophisticated style as well as the expected religious stylization so prevalent in art designed for community expression. Plaster masks presented in this same way adorned the walls of the earliest Maya building yet discovered by archeologists

Photo by Hess

thropology; much of the subject matter is highly ritualistic; we lack an emotional understanding of the Indian character and, therefore, his art, so that the subject matter of his æsthetic seems cold and abstract.

Our western civilization has as a goal the comprehension and the subjugation of nature. In our modern art, we see efforts to recapture and transmit a person, a mood, a truth, or an attitude. The Indian tried rather to establish a magical relationship with nature, wherein, although recognizing the superiority of natural forces, he could constrain or induce them to act in his favor. This attitude persisted even in the highest Indian civilization where magic was transformed into a complex ritual and the tribal surplus was converted to the maintenance of the religion. The service which art has always rendered religion was not neglected in Mexico, but it progressed along the lines of symbolism and ritualistic detail. Thus in content and in presentation, Middle American art is antagonistic to our method of contemplating the universe. However, it is possible to select out elements of Middle American art which can be appreciated intelligently against our own background.

Maya Art

The ceremonial art of the Maya-speaking peoples stands supreme among these ritualistic developments. Every line, every contour, every minor symbol bespeaks tradition and method. Yet the Maya gods were often human personifications of natural forces and in representing them Maya craftsmen reproduced their ideal of beauty. At Copan, in Honduras, during the middle centuries of the first millennium after Christ, a remarkable sculpture in the round was dedicated to this end. The deformed forehead, large nose, astigmatic eye were stressed as important indications of beauty. As would be the case in depicting a fattish people, the contours of the face and body were stressed, rather than the anatomy, and the polishing, pecking, and grinding processes necessary in working stone without metal tools would accentuate the sculptors' interest in surfaces. The Copan stoneworkers succeeded in producing figures which have an aloof repose, fittingly recording the power incarnate in nature. Moreover, these figures were meant to be seen from below and the faces of these gods look down dispassionately upon their worshippers.

The Art of Vera Cruz

An abundance of fine sculpture comes from central Vera Cruz in Mexico and it is easily assimilated in terms of our western æsthetics, for Totonac and Olmec art gives a tantalizing suggestion of Chinese forms, an impression heightened by the skillful reproduction of the Mongoloid features, commonly found in our Indian population. The Totonacs and the Olmecs not only worked in stones ranging in hardness up to jade, but also utilized baked clay as a medium for expression. The latter substance, so subtle and so easy to manipulate, seems to have been neglected by most Old World civilizations as a material for major work of art. Yet its extensive use in Middle America as a medium for major plastic expression may be a result of the absence of the sharp-edged metal tools, essential for wood-carving. In fact, our aversion to this material in our own art causes us to discount some of the most important Middle American art.

The variety which the Olmec and the Totonac attained in their clay sculpture extends to differentiations of physical type, distinction between ordinary and supernatural beings, and even to distinguishing facial expression, and definitely reveals the presence of versatile and sensitive craftsmen. Yet these workers also could combine the abstract designs of a stone ceremonial yoke with an elegantly chiseled profile of purest realism. They could create the chuckling merriment of a laughing head in clay and reproduce a warrior's stern features in porphyry. Another group of clay sculptures recalls the fatigued sophistication of the Ptolemaic art of Egypt.

Arts like these are comparable on direct terms to the great national expressions of the Old World. The jades from southern Mexico rival in sheer intrinsic values of color and design the long-admired jade art of china. Yet there is no doubt of the independent evolution of these two arts.

Aztec Art

The Aztecs are the best known to us of the Middle American peoples. The Spanish conquerors, military and ecclesiastical, studied them carefully, for they represented the full tide of Indian culture at the coming of the whites. Aztec art exemplifies the ceremonial representation of Middle America, enhanced by the balance and rhythm of the profound sense of design, almost universal to Indian art. Yet, given a reason, Aztec craftsmen could reproduce, with singular charm, goddesses who had for them the connotation of youth and spring. The validity of Middle American presentation is amply attested by the works of Diego Rivera, who was the first of his countrymen to thrust away the canons of European bodily proportion in order to portray the anatomical and spiritual qualities of the Mexican Indian.

The peoples of western Mexico never attained the high degree of civilization reached by their eastern

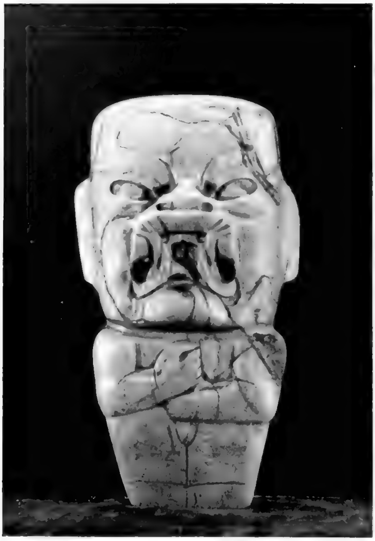
10. *(Left)* FOR SHEER CRAFTSMANSHIP this porphyry mask from Central Vera Cruz is unexcelled by any single art work in the American Museum's vast Middle American collections. Comparison with the Maya heads on page 7 discloses a latent strength in this piece, borne out by the ruggedness of the modern Mexican Indians in contrast to the gentle softness of the present-day Maya. Indian history before the Conquest bears out the mute testimony of the art styles

11. *(Right)* CORN GODDESS OF THE AZTECS carved in basalt. The idea of ripe maidenhood suggested by growing corn is one of the many poetic conceptions which primitive people have applied to their staple food-plants

AMNH Photos

12. *(Left)* LARGE CLAY FIGURE unearthed from an ancient grave in western Mexico. Despite this association with the after world, the comparatively naturalistic treatment of face and body denies that its creators were enslaved by ritual. But one glance at the fantastic Zapotec sculpture at right reveals the work of a people given to the intense ceremonials of a Middle American theocracy. Resembling the many-armed gods of Tibet, this piece does not require experts to point out how the requirements of the local religion had narrowed the range of artistic expression

13. *(Below)* MORE PRECIOUS THAN GOLD from every standpoint was the native American jade from which this beautifully carved ceremonial axe-head was created. The face is that of a deity widely worshipped under various names, who was conceived as having the face of a jaguar or ocelot (large leopard-like feline). Below at right is the head of a Vera Cruz idol wrought in baked clay, a medium favored for the subtlety it permitted these early artists who lacked effective metal tools



AMNH Photo

Photo by Hess

and southern neighbors. Their art, expressed chiefly in clay, is intended to represent but not to symbolize. Both people and animals are represented doing things, although not in violent movement. This passiveness, a sort of monumental inaction, runs through Mexican Indian art, and the modern visitor notices that same lack of violent emotional expression in the present native population. At first oppressive, the effect becomes soothing and calming, counterbalancing the violence of thought and deed in our western world. Equally characteristic of the old Mexico and the new, is a sly, quiet humor which peeps out of the rigors of ceremonial expression even as it bubbles quietly among the modern Indians repelled so far from their once proud state.

North American Art

The North American Indians seldom reached the great heights of ritualistic expression attained in the Central American civilizations. While the builders of the mounds in the middle western and southeastern United States show evidence of considerable artistic ability, for sheer exuberance in design and sculpture the carving art of the Indians of the Northwest Coast stands supreme. Wood was the great medium, and it is tantalizing to think of how little we would know of this art had it not flourished in the latter half of the nineteenth century. Not only do these tribes show the innate Indian ability to use conventional representations in exquisitely designed combinations, but also they produced in their masks, especially, a naturalistic sculpture of startling power, ranging from the sympathetic depiction of a young girl to a medicine man portrayed in the depths of a trance. The bulk of material indicates a tremendous conversion of technical talents to the service of art.

In viewing primitive art, one sees the work of the skilled craftsmen of many nations, tribes and communities. There is a unity to each of these communal expressions of man's search for harmony and beauty. An individual who cannot afford the great masterpieces of the western world may find great content in collecting these minor works of art in accordance with the dictates of his own æsthetic conventions. Another, weary of words, of theory, of propaganda, may find a peace in the feeling of common endeavor which these arts produce, without the accompaniment of torrents of verbalized learning. Despite the individualization of western art, in practice one can pick out the schools, the culture groups, just as among these anonymous arts of forgotten people. If this exhibition means nothing else, it shows that art is a people's common heritage, a field in which all may participate. Let us not let our tendency to specialize and to delegate turn us away from fruitful, active interests for the sake of a sterile admiration of technical superiority.

14. THE MOST ADVANCED ART developed by the North American Indians was the work of the tribes occupying the coasts of British Columbia and southern Alaska. At left is a horrendous monster of mythological significance to its Kwakiutl makers which contrasts with the lovely Haida girl's face below. The modeling of this mask so vividly recalls a living person that portraiture is suggested

All photos by Konrad Cram... a grant from the ... to the Museum

15. *(Below)* THIS KWAKIUTL MASK is intended to show two separate personages. The open wings close to represent another embodiment of the same spirit. Vivid coloring plays an important role in characterizing the mythological being. The colors are used symbolically rather than to enhance the æsthetic values. *(Below right)* No example from the Northwest Coast in the Museum's collection can touch this Tlingit helmet for sheer power. It depicts the warped features of a paralyzed old man revealing an irritable contempt instead of mawkish self-pity

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Roy W. Miner, *Chairman*

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by Roy Waldo Miner

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OF

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What Is a Mollusk Shell?

By Roy Waldo Miner
Curator of Living Invertebrates

Mollusk shells have always been of great interest to collectors. Because of the great number and variety of species, the remarkable diversity of form, color, and size, they have always attracted popular interest and have been fertile sources of motifs to students of design.

From the zoölogical viewpoint, the mollusks are one of the most important groups in the animal kingdom. Next to the insects they include more species than any other animal subdivision, approximately 80,000 being known. The phylum containing them is quite distinct from any other modern group, though the most primitive forms and the free-swimming larvae seem to point to an origin close to that of flatworms or platodes.

Paleontologically, they are one of the oldest groups, representatives being abundant among the fossils of the Lower Cambrian strata laid down at least 600,000,000 years ago. Their shells alone are preserved in a fossil state, but their abundance and the relatively high organization of all mollusks seem to indicate that they existed for millions of years previously, perhaps as naked forms incapable of leaving traces of hard parts in the rocks. It seems likely that the comparatively acid seas of early Pre-Cambrian times when the oceans were more or less free from the salts that accumulated in later ages by erosion from the continents, made the formation of shells of carbonate of lime impossible. Later, when the seas accumulated much calcium in solution, shells were formed, perhaps at first as one of the by-products of excretion, and later utilized and perfected as a means of protection.

The shell is the secretion of the mantle, a thin fleshy fold of tissue that surrounds the upper part of the mollusk's body. As indicated above, it is largely of carbonate of lime, and is laid down as a deposit on a base of delicate horny substance produced by the animal, and spoken of as *conchyolin*. The limy portion takes the form of crystals of calcite or aragonite, standing vertically, or laid down as delicate scales or laminæ slightly overlapping one another. Usually, the shell is composed of three layers: an outer layer of horny integument, rough in character, or raised in hair-like projections in some shells, in others a rough or smooth porcelain-like layer of vertical calcite crystals; beneath this a second calcite or aragonite layer with the crystals laid in another direction; and finally a porcellanous layer like the first. Shells that have an iridescent or pearly lining are usually the more primitive species. In such cases, the two outer layers are very thin, while the inner pearly layer takes up the greater thickness of the shell. This is composed of thin minute plates of calcite arranged horizontally with their edges overlapping like tiny shingles. The light diffracted from the close set lines produced by these edges causes the iridescent effect. The substance of this layer is generally spoken of as *nacre*.

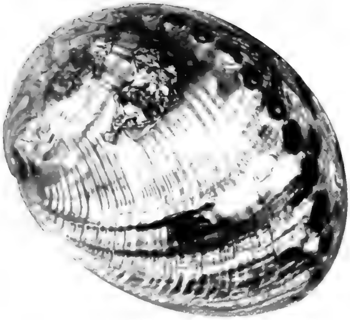
Though the shell is often the most conspicuous part of the mollusk and the part most easily preserved in collections, it is really only a by-product of the animal, and biologically of secondary importance. It bears about the same relation to the animal as a suit of armor bore to a knight of the Middle Ages. If all we knew of a human being were the armor remaining from that period, it would bear somewhat the same relation as would our knowledge of mollusks, if the latter consisted merely in our acquaintance with their shells. The conchologists of the middle and latter part of the Nineteenth Century brought together huge collections of shells from all parts of the world, and, during that time, shell-collecting became a craze and was often the avocation of wealthy men. But the scientists of the time studied shells seriously and with great ability, so that our knowledge of their infinite variety, structure, and distribution advanced enormously, and gradually many facts became known concerning the animals that produced them, as well as their anatomy and life history. Nevertheless the classification of mollusks was based at first almost entirely on their shells and many errors were made that were gradually corrected in later years, when our knowledge of their soft parts was increased. The present-day student of mollusks investigates the animal itself as well as the shell, and gathers all possible facts that will make our knowledge of this group as exact and exhaustive as possible.

From the economic standpoint, mollusks have always been of the greatest importance to the human race. The bivalves, or two-shelled mollusks furnish an enormous food-resource, while the gastropods or single-shelled, snail-like forms, as well as the squids and octopuses, have contributed their part, though to a lesser degree.

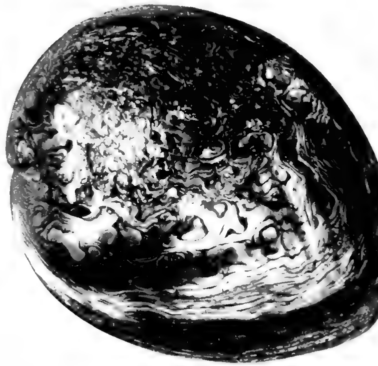
The oyster, clam, and scallop fisheries are by far the most important. Millions of dollars are invested in their development, and thousands of men and great numbers of vessels are employed. Mussels, cockles and razor-shells are also eaten, especially in foreign countries. Among the gastropods used for food in various parts of the world are periwinkles, whelks, conchs, and the luscious abalone.

(Continued on Page 14)

(Left) The Glory of the Sea (Conus gloria-maris). *Enlarged two diameters. This is the rarest and most sought after of shells. It is practically extinct as no specimens are recorded as having been seen alive since 1838, when Hugh Cuming of the British Museum found three specimens on a reef in the Philippines. Not more than a dozen specimens are known to exist and have always commanded high prices. There are two perfect specimens in the collections of the American Museum. The tapering shell suggests an unfolding rosebud. Its porcelain-like surface of pure ivory is completely covered with a mosaic of thousands of tiny triangular figures outlined in chrome-yellow or deep chestnut. Three broad spiral bands of orange encircle the body and, in certain lights, the whole shell is suffused with a faint rosy sheen. The specimen illustrated is five inches in length and was collected in the Moluccas*



A Series of Polished Ear Shells *(Haliotis sp.)*. The series of shells crossing the pages diagonally illustrates the varying surface character of different species of ear shells or abalones when the rough outer layer has been polished off

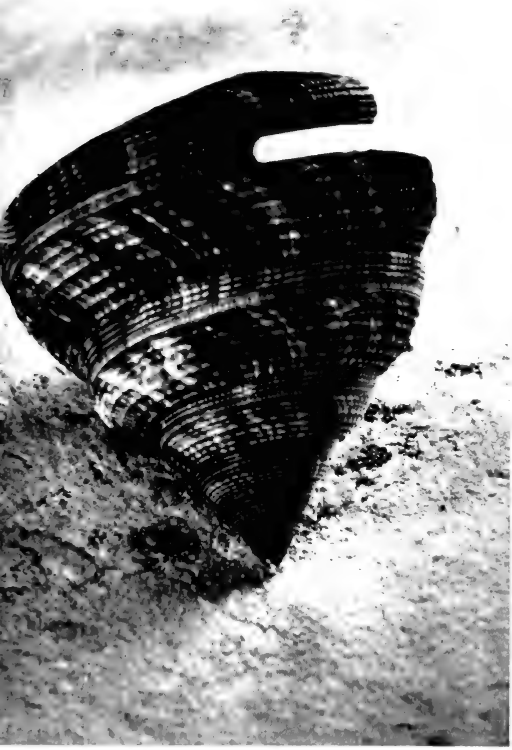


(Below) The Cameo Helmet Shell *(Cassis madagascariensis)*. This shell is not an inhabitant of Madagascar as the scientific name implies. This was due to a mistake of Lamarck, who named it. It ranges along the Atlantic coast of the United States from North Carolina southward and throughout the West Indies. It is one of the largest of our marine snails and was of great commercial value for cameo-cutting when those delicate shell-sculptures were the vogue. Now they are no longer in style and the demand for cameo shells is at an ebb. The shells were formerly exported to Italy and France where the white outer layer was cut into bas relief in skilfully wrought figures standing out against the rich dark brown background of the exposed inner layers of the shell. Ancient cameos were cut in semi-precious stones during classical times. It was not until the early part of the nineteenth century that shells were used for this purpose. The Queen Conch *(Strombus gigas)* was also used to make pink cameos on a white background

(Above) THE BEAR'S PAW CLAM (*Hippopus maculatus*). This is one of the most graceful and fascinating of bivalve shells. It is native to the seas of the Far East, where it is abundant on coral reefs. Both valves are sculptured with a series of rounded and fluted ridges separated by alternating grooves curving over the highly arched shells. These are ornamented with rows of leafy projections and irregular bands of purplish rose rising over the pure white ridges and dipping into the yellow valleys between. The scalloped shell margins neatly interlock as they come together

THE POLISHED SURFACE OF THE ABALONE, as shown by the three diagonal photographs, may be wavy with scattered flutings, comparatively smooth, or thrown into fine parallel ridges. Note the differences in the curving of the spire. The color is a changing iridescence on a background mottled blue to peacock green, red and silver and broken rainbow hues. The lines of the color markings make extremely interesting and often complicated wave patterns. These features are carefully utilized in cutting up the shells for commercial ornaments

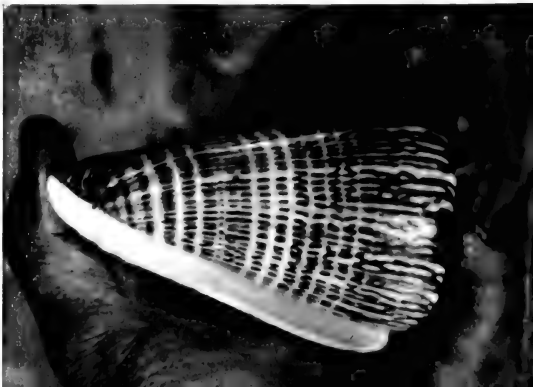
(Below) THE FAMOUS SLIT SHELL *(Pleurotomaria beyrichi)*. This rare shell belongs to a genus once supposed to be entirely extinct, but since 1860 occasional specimens have been dredged alive in deep water in the West Indies and near Japan. It is remarkable for the broad slit extending partly around the outer whorl. As the shell grows this closes from behind. The trail of the closed slit may be seen extending around the spiral of the shell. This photograph (natural size) is of an unusually fine specimen richly colored yellow and red. Fossil specimens occur abundantly since the Cambrian, 600,000,000 years ago



(Above) THE BISHOP CONE SHELL *(Conus episcopus)*. From the Pacific and Indian Oceans. The white, porcelain-like triangular markings are on a chocolate background. Like all cone shells it has a poisonous bite. A tapering proboscis contains two bundles of tiny hollow teeth, each with a poison gland. A painful wound may be inflicted on the hand that picks it up

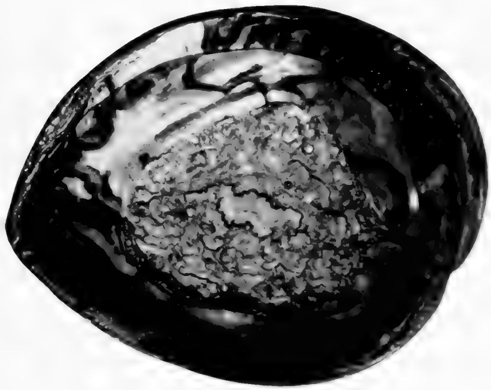
THE PORPHYRY OLIVE *(Oliva porphyria)*. The olive shells have a much shorter spire than the cones and much more rounded shoulders. The outside is like polished porcelain produced by reflected folds of the gay mantle which adorns the outside of the shell in life. The surface in this species is covered with crowded tent-like markings in brown, so it is often called the "Camp Olive." (Gulf of Mexico)

THE THOUSAND-DOTTED CONE *(Conus millepunctatus)*. This cone from the East Indies is completely covered with thousands of close-set brown dots on a white background. Because of their irregular arrangement they resemble characters of some inscribed writing. The spire is quite flat. It is one of the common cones of the Far East. The specimen represented is about five inches in length

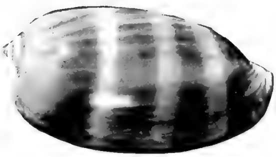


THE SPLENDID ABALONE *(Haliotis fulgens)*. The abalones are also called ear shells because of their shape. There are many species of them found on rocky shores and distributed widely in California, Lower California, Indian Ocean, Australia, Japan and Africa, with one small species in Europe. They are remarkable shells, often of large size, the specimen here illustrated being eight inches in length. The outside is rough with a low coiled spire so that the shell looks like one valve of a clam-like mollusk. Nevertheless it is a true gastropod with but a single shell. The animal has a broad foot enabling it to cling closely to a rocky surface and is pried away with difficulty. The shell has a row of from five to seven round openings along its outer margin allowing a corresponding number of tapering gill-filaments to project from them. Continuing this row is a series of sealed-up openings that were utilized when the shell was younger and were closed as the animal grew. The inside of the shell is lined with beautifully marked mother-of-pearl of peacock green, including the large muscle scar wonderfully patterned in changing iridescent hues. If the rough exterior is ground or etched away, the shell becomes a marvelous object of polished changing sheen. It is utilized extensively for mother-of-pearl ornaments like those shown at the right. Many "abalone pearls," irregular in shape, are found within certain shells and make beautiful objects for which there is a ready sale.

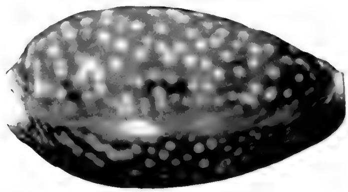
The flesh of the abalone is marketed extensively in China and Japan and is also popular in California for delicious soups, chowders, and "abalone steaks"



THE TURK'S CAP SHELL *(Turbo sarmaticus)*. This is a member of the group of Turban Shells to which the Green Snail *(Turbo marmoratus)*, shown on p. 13, also belongs. The species shown at the left is abundant at Cape Town, South Africa, where it forms an important article of commerce. The outside of the shell is brownish red and comparatively rough in the natural state, with a layer of black underneath, but this thin coat can be readily ground or rubbed off, leaving the entire shell of a beautiful pearly lustre with translucent greenish clouds. The shells are cut to adorn various articles such as knife handles, purses, cigarette cases, card cases, as well as various forms of jewelry



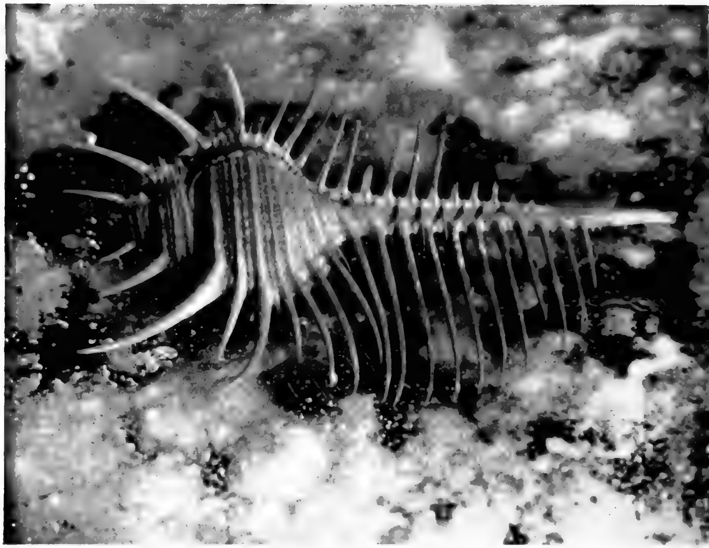
(Left and below) THE MEASLED COWRY *(Cypraea exanthema)*: The common cowry of the West Indies. Usually patterned with light round spots on a chestnut ground having bluish gray clouds. Some specimens are entirely without spots like the shell to the left. Often found crawling up mangrove stems in Southern Florida and Bahama swamps. Like other *Cypraeas,* the polish of the shell is due to the action of the reflected folds of the shell-forming mantle which covers it in life



(Below) THE IMPERIAL HARP SHELL *(Harpa costata)*. The graceful shape of this beautiful shell suggests the name applied to it and its relatives. Naturally polished by the mantle of the animal, and variegated with rich coloring heightened by the bright orange of its lining, it is one of the most attractive of mollusks. This species is distinguished by close-set prominent ribs

Triton's Trumpet (*Triton tritonis*). This shell sometimes grows to 18 inches in length. Its graceful form suggests a trumpet, for which purpose it has often been used by cutting a hole at the tip of its spire. It is remarkably colored with purple, brown, and reddish crescents on a light ground, each crescent just occupying a whorl width, and giving the effect of a gayly colored bird's plumage. At intervals along the spire may be seen the sharp edges of "varices," the former lips of the shell-opening when growth was arrested in successive stages of its life-history. The shell above was photographed in front of a mirror to show both sides.

The Orange Cowry (*Cypraea aurantium*). This brilliantly polished richly orange-colored cowry is prized by collectors both because of its rarity and beauty. It is found outside the reefs in deep water in such Pacific Islands as Fiji, the Solomons, and the Loyalty Group. Among the natives the wearing of these shells is considered one of the highest honors to be conferred by a chief, paralleling an Order of Merit among European nations

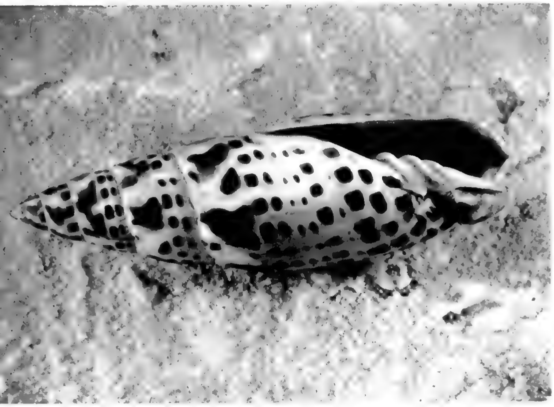


(Above) THE VENUS'S COMB SHELL *(Murex tenuispina)*. The Family Muricidae, to which this remarkable shell belongs, is a large one containing many species of highly organized, carnivorous mollusks spread throughout the world, especially in warm seas. Many of the species are characterized by grotesque or graceful spine formations. The slender lower shell-margin is extended forward to form a long "canal." Six varices, each with a row of delicate attenuated spines, give the name of the shell. To this same family belong several species of *Murex* or *Purpura* which produce a beautiful purple dye from the anal glands. It was *Murex brandaris* of the Mediterranean that furnished the Tyrian purple dye of the ancients and the royal purple of the Roman emperors

(Left) THE GREAT SCREW SHELL *(Turritella terebra)*. The gracefully turned spires shown at the left taper to a sharp point and sometimes attain a length of five inches. They are found in the Philippines and the Far Eastern Seas. It is said that such a shell suggested to Archimedes the principle of the screw

(Below) THE PAINTED THORNY OYSTER *(Spondylus pictorum)*. The genus containing these strange and beautifully tinted bivalves has been known since the time of the ancient Greeks, and they have always been favorites with shell collectors. They inhabit tropical seas. The species shown below comes from Lower California. Its spines are rose red and often orange or yellow

THE GREAT ARK SHELL (*Arca grandis*). The heavy box-like valves of the ark shells give their name an appropriate significance. There is a strong bristling epidermis on the outside. The shells fit together closely, their thirty or more ribs interlocking. The hinge is very long and has a large number of teeth in comb-like series. The valves are strongly arched with curving beaks separated by triangular excavations spreading to the hinge. Viewed edgewise a lateral extension of this area has a heart-shaped outline. (Common from Cape Cod to the West Indies)



THE EPISCOPAL MITRE SHELL (*Mitra episcopalis*). The Mitre Shells are widespread in tropic seas. There are more than 200 species, many of them brightly colored and much sought after by collectors. The Episcopal Mitre shown here has a white porcellanous shell. The closely compressed whorls form a graceful tapering spire with slightly convex outlines. It is conspicuously marked with bright orange spots nearly quadrangular in shape and neatly arranged in rows, except for those directly under the sutures of the whorls which are large irregular blotches. The shell-opening is streamlined with the general curvature of the spire, and several large "teeth" adorn the columella or central stem

THE SPIDER SHELL (*Pterocera bryonia*). This strange shell is related to our West Indian Queen Conch (*Strombus gigas*), but is native to Tahiti. It is massive, often a foot in length. The outer surface is rough, but the lining is beautifully enameled with rose blending into orange. The long pointed projections from the edge of the shell-margin at first hollow but later becoming solid, grow out as the shell attains the adult condition and when it is moving over the sea-bottom it suggests the appearance of a huge spider

THE PEARLY OR CHAMBERED NAUTILUS (*Nautilus pompilius*). This remarkable creature belongs to a bygone age. It is the only surviving species of a long line of fossil forms reaching back 500,000,000 years or more. It is a member of the Cephalopoda, the group which includes the squids and octopuses. The outer layer of shell is porcellanous, pure ivory in color. Otherwise the thickness of shell is mother-of-pearl of a most beautiful lustre, much used in manufacture of fancy articles. Within the hollow coil of the shell there is a succession of cup-shaped chambers diminishing in size until the smallest and earliest formed is reached at the center. The animal, with its many tentacles, lives in the outer chamber, as seen above at the right

(*Left*) The lower valve of this *Spondylus* or Thorny Oyster has become attached to the branches of a cluster of dead coral

(*Right*) NORTHERN SCALLOP (*Pecten islandicus*), first discovered in Iceland, whence its name. Most brightly colored of the scallops, it is banded in red, orange, purple or pink

THE SPINDLE SHELL (*Fusus proboscidiferus*). The Spindle Shells are found in warm seas and all are huge shells. The species shown is the giant of them all, at times reaching a length of two feet. The whorls of the spire are bordered with knobbed ridges. The shell tapers to a long open canal which is undulate and slightly bent to one side. Another open tube, the umbilicus, penetrates the spire and runs parallel to the canal above mentioned. The color is light brownish yellow and the outside is often covered more or less with a silky epidermal coat. This specimen came from Australia

BEFORE AND AFTER POLISHING: The Green Snail (*Turbo marmoratus*). This is the largest of the Turban Shells. It is characterized by the horny outer layer of green, variegated with brown and whitish blotches. When this is ground off, a beautiful greenish pearly lustre is exposed, brightened by rainbow tints. Early Scandinavian kings used these shells for drinking horns. Examples have been preserved elaborately mounted in silver and adorned with jewels. The shoulders of the low spire are raised in a heavy ridge, and a row of large knobs stands out on the lower part of the body whorl, as shown to the left below. To the right is a fine specimen which has been ground to show the mother-of-pearl beneath. These shells are abundant in Eastern Seas, and the animal is used for food in Japan

(Continued from Page 3)
Many other forms are consumed locally by the natives of different countries where they are plentiful.

For other economic products than food the pearl-oyster is of outstanding importance, not only for the precious pearls occasionally produced, but also for the mother-of-pearl, which is used extensively for the manufacture of buttons, knife-handles, inlays, and all kinds of fancy ornaments. All nacreous shells of other species have varying value in this respect, the most important being the fresh-water clams, abalones, top-shells, and the turban-shells. Certain cowries have been used for money in the Far East and the Pacific Islands, while the American Indians used shells of the hard clam for making wampum. The tusk-shell also was utilized for this purpose by the Indians of the northwestern states. Shells have been used for various utensils, such as spoons, knives, dishes and basins. Tritons and conchs have been widely used as trumpets. The Purple Snails were crushed by the ancients and by many native Indian tribes for purple dye. Shells are ground up for road-making and are burned to obtain lime. Many of the beautiful species are used for ornaments such as necklaces, shield-decorations, earrings and the like. The great Orange Cowry is highly prized as a mark of rank of Fiji chieftains. The larger and more beautiful shells are doubtless used by many of our readers as household ornaments and curios and shell-collecting is progressively becoming of widespread general interest.

The mollusks are classified in five main groups, as follows:

The *Amphineura* or Chitons and their relatives. These are the most primitive of living mollusks, the larger number of them having an oval, creeping body with a jointed armor of eight transverse plates. They have a certain serial repetition of body-parts and breathe by means of a double row of plume-like gills.

The *Gastropoda* or snails. This is the most important group in number of species, distribution, and extent of diversification. They are the most ancient from the standpoint of fossil remains. The earliest shells resembled a "liberty cap," being cone-shaped with the shell uncoiled. Soon forms appeared with a one-sided roll; and a little later the spirally twisted, right-handed shell was established and has been generally characteristic, ever since. The twist of the shell is reflected in the internal anatomy. In some gastropods the shell has become reduced, and in others it has disappeared entirely.

The *Scaphopoda* or Tusk-Shells are relatively unimportant comprising only a few species. They possess a shell shaped like an elephant's tusk open at both ends.

The *Pelycypoda*, or bivalves, have the mantle divided into two halves each of which secretes a shell. They are hinged together and are nearly equal in size. The foot is flattened vertically and extends down from the enclosed body-mass. It may be protruded from between the two shells for digging or swimming. Delicate, flattened and fine-meshed gill-flaps on either side furnish breathing organs and an arrangement for filtering out food-particles.

The *Cephalopoda* include the swiftly moving squids, cuttlefishes, and octopuses. This highly organized and specialized group is composed of predaceous species with efficient eyes and method of propulsion of a peculiar kind. The Pearly Nautilus is the most ancient type. It is illustrated and described elsewhere in this article. The shell is well-developed in this species, but shows progressive degeneration in most of the squids where it becomes internal, and practically disappears in the octopuses. Thus the members of the group are freed from hampering armor to make possible a vigorously active life.

The American Museum of Natural History has an unusually extensive exhibition series of shells displayed in the Hall of Ocean Life. The accompanying photographs illustrate a few outstanding examples taken at random from the Museum shelves.

WHITNEY MEMORIAL HALL of PACIFIC BIRD LIFE

By Robert Cushman Murphy

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ROBERT CUSHMAN MURPHY, D.Sc.

Curator of Oceanic Birds

GUIDE LEAFLET SERIES

of

THE AMERICAN MUSEUM OF NATURAL HISTORY

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WHITNEY WING

The new home of the American Museum's Department of Birds

By ROBERT CUSHMAN MURPHY

On June 6, 1939, the Whitney Wing of the Museum, which extends northward along Central Park West from the Roosevelt Memorial Building, was formally opened in the presence of Mrs. Harry Payne Whitney and members of her family, the trustees of the Museum, the scientific staff, delegates from sister institutions and other invited guests. Addresses in celebration of the occasion were made by President F. Trubee Davison, by Mr. Cornelius Vanderbilt Whitney and Dr. Leonard C. Sanford, who are both trustees, and by Doctor Frank M. Chapman and the writer, of the staff, after which the visitors inspected the structure throughout its eight floors.

Whitney Wing is the result of a gift from the late Mr. Harry Payne Whitney which was equalled by an appropriation from the City of New York. The dedication of the building and the relation of the patrons to the Department of Birds are explained by an inscription on the second floor, which reads: "This wing of the Museum is the memorial of Harry Payne Whitney to his father, William C. Whitney. After the death of the donor, the collections of birds were greatly enlarged and the exhibits in the building completed in his memory by his wife and children."

Whitney Wing is the most commodious and best equipped ornithological headquarters in the world. It also houses the largest and most important collection of birds, numbering approximately 750,000 specimens. Coördination of the Museum's older material with the Rothschild Collection (likewise a gift from Mrs. Whitney and her children) and the birds obtained during the Whitney South Sea Expedition has produced an orderly systematic arrangement in new steel cabinets on seven floors of the building, so that every specimen of an ornithological nature is now readily available to investigators. In addition to offices and the "ranges" in which preserved material is safely stored, one floor of Whitney Wing is equipped with laboratories in which living birds may be bred and kept under observation in the course of studies relating to heredity and behavior.

Three floors are devoted in whole or in part to exhibition, these comprising an Art Gallery, a Hall of Biology of Birds and the Whitney Memorial Hall of Pacific Bird Life. The last, which is the present "show place" of the department, opens from the main entrance hall of the Museum in the Roosevelt Memorial and thus balances the Hall of Asiatic Mammals and the Akeley African Hall.

Whitney Memorial Hall is at present about half completed and its exhibits are the subject of the following eight pictorial pages. Its wall cases provide for eighteen habitat groups of Pacific birds, of which eight have thus far been installed and opened to the public. Ultimately these displays will cover the Pacific Ocean by means of selected localities extending from the Galápagos Islands and the coast of South America on the east to the Philippines, New Guinea and the Australian Barrier Reef on the west; and from islands near Hawaii, in the northern hemisphere, southward to one of the small outliers of New Zealand, on the verge of the Antarctic. Directions in the hall are similar to those on a map. The visitor, entering at the south end, finds himself abreast of a group illustrating bird life of the West Wind Zone, in high southerly latitudes, and then walks northward through the tropics into the northern hemisphere as far as the island of Laysan, at the edge of the North Temperate Zone, which is the latest of the eight exhibits thus far completed. The succession of bird life exhibited in the sky overhead follows the same plan, leading from Antarctic Snow Petrels and Whale-birds to equatorial Man-o'-War Birds and Tropic-Birds.

Mural charts in the entrance halls serve a purpose both of decoration and orientation; on them the visitor will find the exact location of each exhibit, as well as information about ocean depths, prevailing winds and currents and other geographic factors that have had much to do with the present distribution of life in the Pacific. One of the four maps shows also the division of this greatest of ocean basins into its natural geographical regions, both of the sea and of the archipelagoes, and the courses of a limited number of vessels notable in the history of Pacific science. These comprise the tracks of the pioneering ships 'Resolution' and 'Discovery' (1776-1780), commanded by James Cook; those of the Russian cruise of the 'Vostok' and 'Mirnyi' (1820-1821), under F. G. Bellingshausen; the famous voyages of the 'Beagle' (1832-1836) and 'Challenger' (1874, 1875); the surveys of the United States Fish Commission steamer 'Albatross' (1888-1910); and, finally, the lengthy wanderings of the American Museum schooner 'France' (1922-1932),

during the Whitney South Sea Expedition. The first mural, at the right of the entrance to the Hall, is an enlargement of a chart published by Abraham Ortelius, of Brabant, in 1589. It reveals the European conception of the Pacific Ocean three and a half centuries ago, and includes a basal shield in which the Museum acknowledges its debt to two generations of distinguished patrons, personified by William C. and Harry Payne Whitney.

The reproductions of photographs on succeeding pages offer only a fragmentary idea of the Hall, since many of them depict no more than small details of the several groups. The latter are, however, labeled in such a manner that Museum visitors can readily identify every element of the bird life and find a record of the part played by each of the many individuals who have cooperated in the creation of this notable exhibition.

(Below) ONE HALF OF THE EXHIBITS of bird life designed to reproduce in miniature the far-flung islands of the Pacific. The dome of the sky seems to rest upon the common oceanic horizon of backgrounds. Suspended beneath the clouds by invisible wires are sea birds chosen to match the respective life and latitudes of scenes in the cases, which represent localities in the Pacific between the Antarctic and the North Temperate Zone, including coral and volcanic, low and mountainous, islands, some of which are covered with teeming rain-forest vegetation while others are bare and arid. The memorial busts are portraits of Harry Payne Whitney (1872-1930), by Jo Davidson, and of his father, William C. Whitney (1841-1904), by Augustus St. Gaudens

-FOLLOWERS of the "Roaring Forties." Far south where strong westerly winds prevail over an ocean almost unbroken by continental land masses, vast numbers of petrels and albatrosses spend their whole life on the open sea except during the weeks of their breeding season. Such birds often follow sailing ships for food stirred up in the wake or tossed overboard, or because attracted by mere curiosity. Sooty and Wandering Albatrosses, Cape Pigeons, Whale-birds, Mother Carey's Chickens and other Petrels show in this scene, southeast of New Zealand in mid-summer (February). Beyond the bulwarks and rigging of the vessel on which the observer is supposed to stand, can be seen the Whitney Expedition schooner *France* running under shortened sail before the brave west winds. (Numerals adjacent to photographs refer to locations indicated on the maps)

AMNH Photo by Bierwert

1

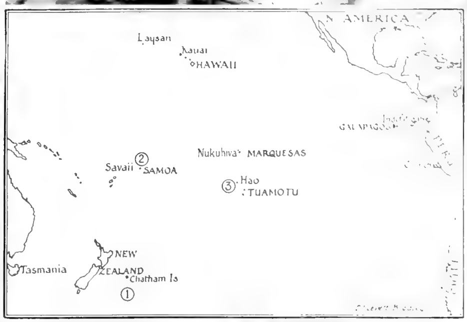
2

The Tooth-billed Pigeon: detail of the Samoan exhibit. This odd bird, which has been given the scientific name *Didunculus* because of a fancied resemblance to its big extinct relative, the Dodo, is the most striking and peculiar of all the birds of the Samoan archipelago. It lives on the two large islands of Savaii and Upolu, and nowhere else in the world. Although it is a member of the large, varied and widely distributed pigeon family, the Tooth-bill of Samoa has no very near relatives and is probably a relic of a branch of the pigeon group that has long since died out elsewhere. The Samoan exhibit as a whole shows a point on the slopes of Savaii where forest and grassland meet and where woodland birds consequently come into contact with those of the open

AMNH Photo by Bierwert

Life on an atoll in the Tuamotu archipelago: the island of Hao, showing the nesting ground of Man-o'-War Birds, Tropic-Birds, Boobies, seven species of Terns, the Reef Heron and the extremely rare Polynesian Sandpiper, of which a pair stands in the left foreground. The birds face the trade wind toward the pounding coral reef, with the lagoon of the islet showing at the left behind swaying coconut palms and pandanus

AMNH Photo by Coles



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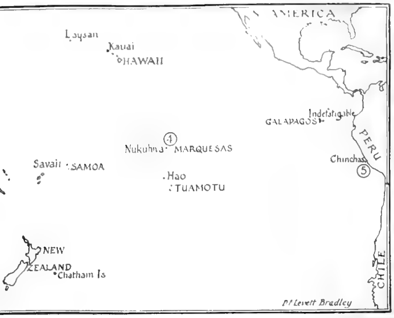


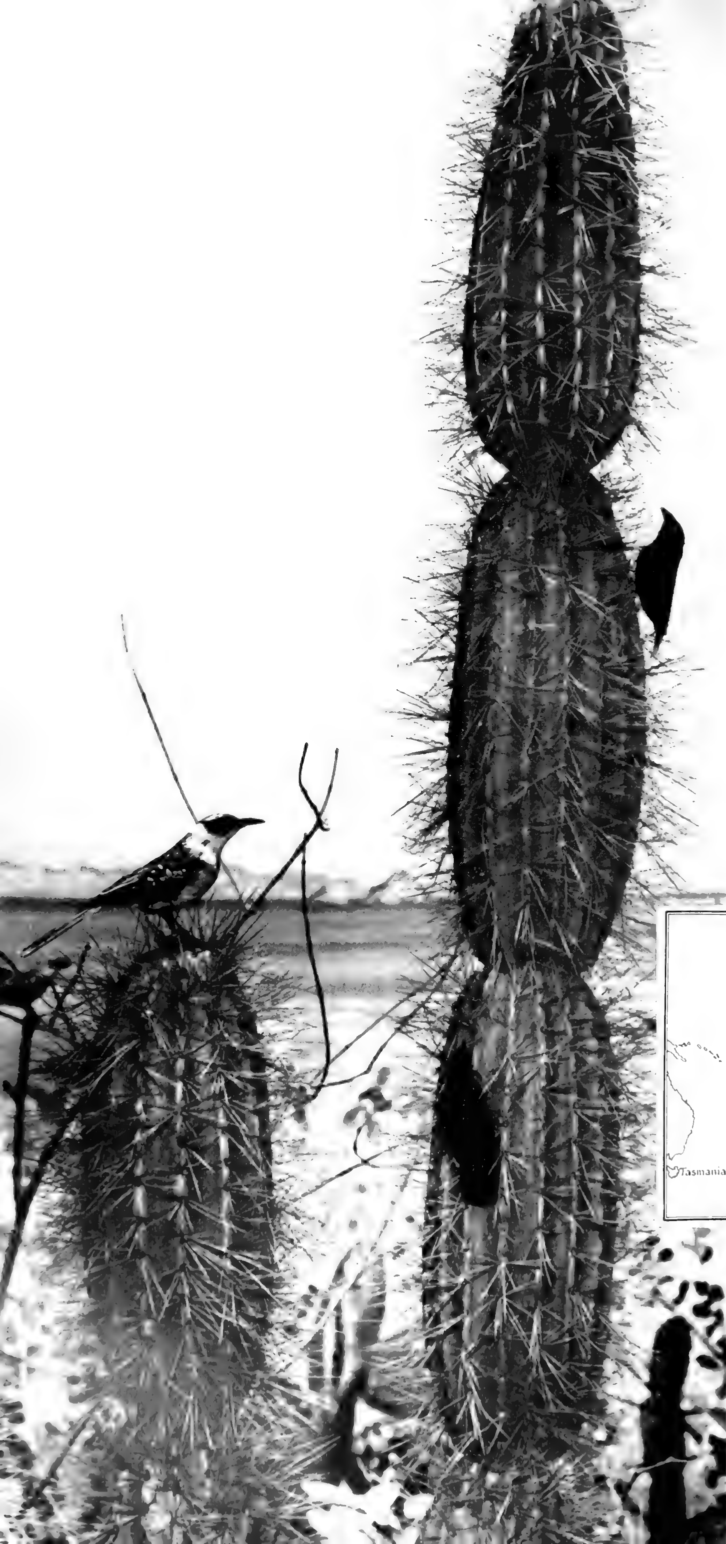
(Left) MARQUESAN FAIRY TERN: detail of the Nukuhiva exhibit. Most delicate of sea birds are the Fairy Terns, with their pure white plumage and huge dark eyes. This one has poised on filmy wings on the bough of a South Sea hibiscus. The exhibit as a whole shows a view over the valley of Taipi, scene of Herman Melville's "Typee" (1846), a romance of primitive life in the Marquesas Islands

(Right) GUANAYS, or guano-producing Cormorants, of the coast of Peru: detail of the guano island exhibit. A fledgling *(at left)* is begging its parent for food. The Guanay has been judged upon a purely economic basis "the most valuable bird in the world"

AMNH Photos by Coles

PERUVIAN GUANO ISLAND EXHIBIT: a scene at the far-famed Chincha Islands, looking southward across the Bay of Pisco. Peruvian Cormorants, Boobies (on the cliff at the left), and Pelicans make up a distinguished trio of sea birds which produce annually in this rainless region more than a hundred thousand tons of marketable fertilizer worth 33 times its weight in farmyard manure. Guano exploitation in Peru constitutes the largest industry based upon the conservation of wild birds

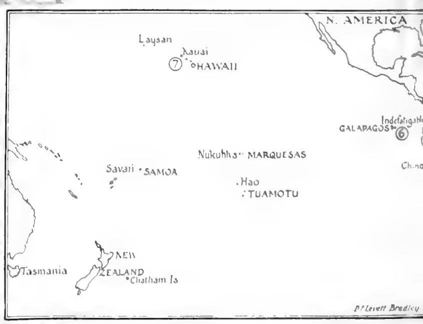
5



6

Mockingbird and Cactus Finch: detail of the Galápagos exhibit. The view is from James Island toward Albermarle. The volcanic Galápagos Islands, which straddle the equator about 600 miles west of South America, have been isolated for long ages, and the origin of their peculiar plant and animal life poses many scientific problems. The Cactus Finch, climbing the prickles, is a member of a family of land birds (Geospizidae) found nowhere else. Nine species inhabit James Island alone. The curious specializations of the bills of these birds gave Charles Darwin, who visited the Galápagos during the cruise of the "Beagle" in 1834, his first ideas regarding "natural selection" as a mechanism to explain the process of evolution

AMNH Photo by Coles



6

Galápagos Hawks: detail of the exhibit. Fearlessness is a striking characteristic of the varied wild life of the Galápagos. It doubtless indicates an enormous period of time without molestation from man or four-footed enemies. Although dogs, hogs, goats, cattle and donkeys have been introduced and have reverted to a wild state, the native Galápagos animals retain a surprising tameness. These hawks illustrate two color phases of a resident species belonging to the cosmopolitan genus of our American Red-shouldered Hawk. They sometimes perch on the hats of visitors and readily step from their perches onto a proffered stick

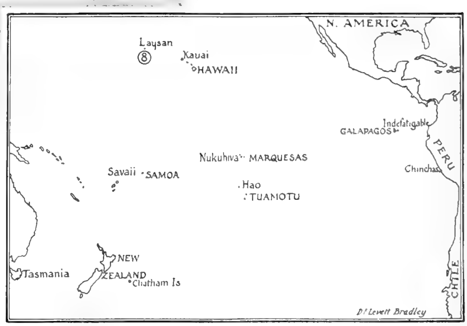
AMNH Photos by Coles

Scarlet Sickle-bill (Hawaiian Group): a bird important in the human history of Hawaii because from its red feathers the gorgeous ceremonial capes of the ancient island chiefs were made. The Sickle-bill is a member of the curious family of Hawaiian Honeycreepers (Drepanididae), confined entirely to this mid-Pacific archipelago. Although all closely related, the numerous species show remarkable variations in the bill, correlated with diverse feeding habits. This exhibit looks down a great canyon on the island of Kauai to the ocean four thousand feet below

7

WANDERING ALBATROSSES: detail of the dome. This is the largest bird that flies, with a maximum wing-spread of eleven feet four inches. The huge sea fowl is one of the southernmost of its family, nesting on bleak islands close to the Antarctic and spending the greater part of its life on long travels over oceans well south of the equator

AMNH Photos by Coles



LAYSAN ALBATROSSES AND BRISTLE-THIGHED CURLEWS: detail of the Laysan Island exhibit. Laysan is an islet in the long chain northwestward of Hawaii. It was created a reservation by executive order of President Theodore Roosevelt in 1909, since when the resident birds have been free of the human marauders from which they had previously suffered greatly. The Laysan Albatross is one of three North Pacific species of its family, two of which nest at Laysan in impressive numbers. These birds return each year to dance and mate, not in our spring season but in November, the springtime of the southern hemisphere, where most of their relatives live. The Bristle-thighed Curlew breeds in Arctic Alaska and makes Laysan a way station on its long migration toward islands in the South Pacific

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THE ORIGIN OF THE DOG

By EDWIN H. COLBERT

With drawings by MARGARET M. COLBERT *and* MORGAN STINEMETZ

Science Guide No. 102

THE AMERICAN MUSEUM OF NATURAL HISTORY

THE ORIGIN OF THE DOG
Wild Dogs and Tame—Past and Present

BY

EDWIN H. COLBERT

Curator of Fossil Reptiles, Amphibians and Fishes
American Museum of Natural History

ILLUSTRATED BY

MARGARET M. COLBERT AND MORGAN STINEMETZ

Science Guide No. 102

NEW YORK CITY

The American Museum of Natural History

1946

THE ORIGIN OF THE DOG
Wild Dogs and Tame—Past and Present

A panorama of the origin, genealogy and "social" background of the tractable wolf that emerged from the wilderness to become man's best friend

TO THE casual observer the numerous breeds of domestic dogs would seem to have reached the farthest possible limits of diversity among animals that may still be called by one name. And so they have, in one sense of the word. Compare, for a moment, the Great Dane with the Scotch terrier, the old English sheep dog with the Chihuahua, or the greyhound with the bulldog. Certainly there appears to be but little in common between these dogs, at least in their outer form, even though they are all dogs. One wonders what some future zoologist or paleontologist might do with the breeds of modern dogs, were he to find their bones among the ruins of what we are pleased to call our present-day civilization.

SIMILAR PSYCHOLOGY

Yet we know that the collie and the Yorkshire terrier and the Pomeranian are all dogs, because we have seen them originate and develop—so to speak—under the controlling influence of man's hand. Moreover, we know that they are all dogs because of their habits, for in spite of the dissimilarities in their appearances, they act much alike—they are all dogs by instinct and by reason of their peculiar psychology and the workings of their canine brains.

And when we get down to such a fundamental comparison as this we bump into the fact that the domestic dog, no matter what his looks may make him, is under the skin nothing more nor less than a tractable wolf—or, to look at it from another angle, the wolf is nothing more nor less than a wild dog.

The origin of the dog is lost in the mists of antiquity, for of all the animals domesticated by man, the dog was the first. Since the time when the question of the dog's origin was first seriously investigated, numerous attempts have been made to ferret out what his ancestors might have been, but despite diligent studies toward this end no definite conclusions have been reached. Indeed, zoologists differ among themselves, and at best they can for the most part only indulge in scientific speculations regarding the ultimate ancestry of the dog.

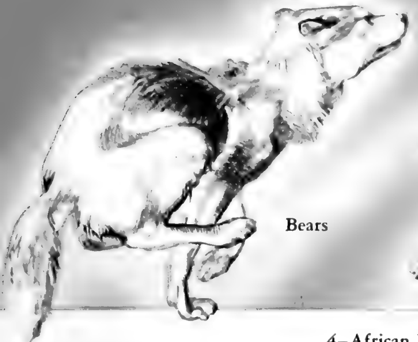
Generally speaking, most authorities agree that the dog is largely descended from the Eurasiatic wolf. Perhaps the story of the origin of the dog is a complex one, in that wild dogs have been severally and independently domesticated by man at different times in different parts of the world, while on top of this the dog after his domestication has perhaps often been crossed back with various wild dogs at different periods during the rise of human cultures. Certainly we know that the Eskimos, for instance, not infrequently cross their sledge dogs with wolves, to maintain the strength and endurance of the breed.

BACKGROUND OF DOG TRIBE

Which is to get back to a point made before, that the dog is nothing more than a tractable wolf —or tame wild dog, if you will. And to understand

THE ORIGIN OF THE DOG

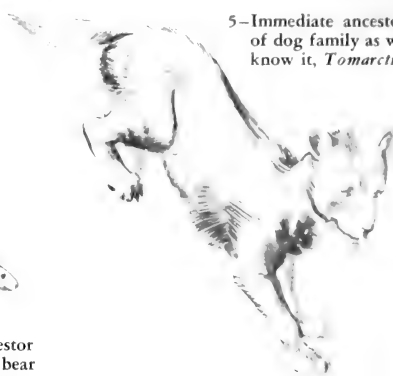
Compiled by Edwin H. Colbert *Drawings by* Margaret M. Colbert



Bears

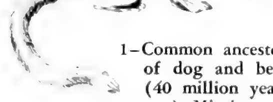
7–The wolf, whose tractable descendants developed under man's guidance

4–African Hunting Dog (wild), *Lycaon*



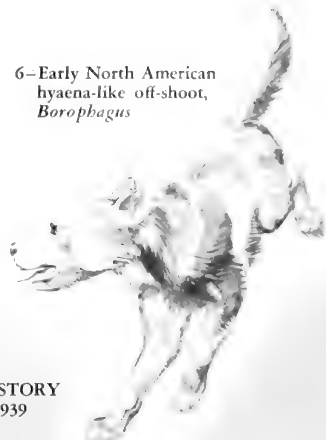
5–Immediate ancestor of dog family as we know it, *Tomarctus*

3–First "Bear-dog," *Daphaenus*



1–Common ancestor of dog and bear (40 million years ago), *Miacis*

2–Grandfather of all dog family, *Cynodictis*



6–Early North American hyaena-like off-shoot, *Borophagus*

THE prehistoric development of the wolf, from which the dog sprang, is typified chiefly by increase in running speed. The dog's ancestor *Cynodictis* (2) of some 20 or 30 million years ago was a slender, short-legged animal perhaps no larger than a mink. This animal began a line of evolution characterized by ever-increasing leg length and the development of an almost unique ability to run down prey mile after mile and seize it. This led to important "social" developments, involving group hunting. Competition, in turn, stimulated the growth of intelligence, along lines quite different, for instance, from that of the solitary cat. *Cynodictis* gave rise to two branches, one leading to the modern African Hunting Dog (4) and one through *Tomarctus* (5) to the wolves and domestic dogs. *Tomarctus* (of some 15 million years ago) differed but little physically from the wolves and wild dogs, but doubtless had far to go in intelligence. In modern times many widely different dogs have been bred, but the intelligence and adaptability of the dog remain distinctive.

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this question of the domestication of the dog, it may be well, perhaps, to review the story of the origin and evolution of the dog and his cousins—to get a glimpse at the background of the dog tribe, the better to appreciate those characters that make dogs what they are.

The dogs, the wolves and their relatives belong to a family of carnivorous mammals known as the *Canidae*. This family includes, in addition to the dogs and wolves, the jackals, coyotes, dingos, the various dogs and foxes of South America, the Japanese "raccoon-dog," the numerous northern foxes and the fennec, and finally the African hunting dog, the East Indian wild dog, or dhole, and the South American bush dog. Even to the non-zoologist, these creatures are clearly recognizable as being related to each other, because of their general dog-like or wolf-like appearance. And in addition to these modern dogs there is a host of extinct canids, for the most part known only to the trained paleontologist—many of them of course very much like our modern dogs, but many more quite different from anything in the canid line surviving to the present day.

The canid or dog family (and here we use the word "dog" in an inclusive sense, to designate the numerous canids listed above) had its beginning some 40 million years ago, during the transition from the Eocene to the Oligocene period of geologic history. Those were the days when horses were no larger than small sheep, and had three toes on each foot, when rhinoceroses were still small horse-like running animals, quite hornless and probably completely lacking in the ferocity

MIACIS

that so distinguishes their modern descendants; when camels were dainty, gazelle-like creatures; and when the first ancestors of the great apes and the man were small, tree-dwelling monkeys.

In those far-off days there lived a small carnivorous mammal known as *Miacis*, the offspring of some very primitive Eocene carnivores that had passed through the heyday of their evolutionary supremacy and were on their way to extinction.

Miacis was a small carnivore with a long body and relatively short legs—not so different in appearance from some of the modern East Indian or African civets, which are but the slightly changed descendants of this primitive ancestor. Perhaps *Miacis* spent a considerable part of his time in the trees, for it would seem probable that the earliest true carnivores dwelt in the primitive forests that sheltered so many ancestral mammalian types. This early carnivore, structurally

FIRST OF THE "BEAR-DOGS" (*Daphaenus*)

and mentally in a low stage of development, seems to us to have taken but a slight step in the direction leading to its progressive heirs, yet in spite of its primitive form it had the potentialities that were destined to lead into a large and varied group of highly advanced mammals.

During the Oligocene period the first canids evolved in North America as the direct lineal descendants of *Miacis*. Of these there were two types, one a large, heavy, long-tailed dog known as *Daphaenus*, the other a much smaller, more slender animal, going by the name of *Cynodictis*.

Daphaenus was the first of the "bear-dogs," an animal as large as a coyote but longer-bodied, with relatively shorter legs, with a massive skull and an unbelievably long, heavy tail. These animals became progressively larger as time went on, until during late Miocene days (some 10 million years or so ago) they grew to truly gigantic proportions. Then some of them followed a line of evolution that involved a marked increase in weight, a secondary change from the typical run-

ning habits of the canids to a lumbering type of walk—due to the shortening of the feet—and profound modifications of the skull and teeth. Thus the bears arose, as descendants of the bear-dogs, in early Pliocene times.

GRANDFATHER OF ALL DOG FAMILY (*Cynodictis*)

As this first of the "bear-dogs" began to develop in the direction of the bears, the grandfather of all the dog family appeared. This animal, *Cynodictis*, retained the long body and short legs of the primitive carnivores. Indeed, like its ancestor, *Miacis*, it must have resembled to a considerable extent the modern Old World civets. And it was still so close to its earlier tree-climbing ancestors that it retained partially retractile claws, something like those of a cat.

This ancestor of the true canids gave rise to two distinct types of "grandchildren" in lower Miocene days.

One of these canids, *Temnocyon*, was ancestral to an evolutionary line that culminated in the modern hunting dogs of Africa and India. The African hunting dog, *Lycaon*, is a large, mongrel-looking canid with erect, rounded ears, and

AFRICAN HUNTING DOG (*Lycaon*)

marked by irregular brown and yellow spots. The East Indian hunting dog, or dhole, is very dog-like in its general appearance, with a long, pointed face, a bushy tail and a reddish coat. These canids, so like ordinary dogs to the casual observer, are in reality of quite an independent ancestry, and it would seem that the peculiar South American bush-dog, *Icticyon*, with an abbreviated face and a short tail, is, strangely enough, related to the Old World hunting dogs.

The other of these two lower Miocene canids, *Cynodesmus*, was the ancestor of a large and varied group of dogs, including our modern Eurasiatic and American dogs, wolves and foxes, which went through a major portion of their evolutionary development in North America.

Among the offspring of this ancestor of our common dogs (*Cynodesmus*), one branch, completely North American in its distribution and destined to become extinct, developed along a peculiar line whereby its members became very large, and strangely enough, hyaena-like. This does not mean, of course, that they are to be related to the hyaenas, but rather that they de-

"HYAENA-DOG" (*Borophagus*)

veloped by *convergence* in a way similar to the hyaenas, because they lived the same kind of a life that the hyaenas live today. These dogs were the "hyaenas" of their time, occupying a rôle in North America that the hyaenas, which were just beginning to evolve along their strange line of evolutionary development, were learning to play in the Old World. These "hyaena-dogs," the most characteristic of which were *Hyaenognathus* and *Borophagus*, had heavy, bull-dog like skulls, with extraordinarily strong blunt teeth, adapted to crushing bones, rather than to slashing or tearing, for like the hyaena, these dogs were carrion feeders.

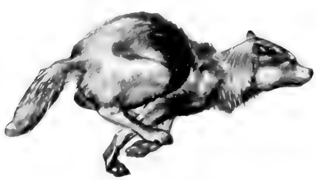
Finally, we may consider the true dogs as we know them, which evolved between upper Miocene and recent times as an offshoot from the *Cynodesmus* stem and had their immediate origin in a genus known as *Tomarctus*.

Tomarctus must have been very dog-like in its general appearance, and with but little change, except for the important one of the growth of intelligence, it grew into the wolves and wild dogs that spread throughout the northern world

FATHER OF DOG FAMILY (*Tomarctus*)

and surrounded primitive man in the East. From this ancestral form there evolved also, along a somewhat different line, the foxes, and the fennecs, small desert foxes of Africa.

Reducing these facts to their simplest terms, it may be said then that the canids, or "dogs" have followed four general lines or trends of evolutionary development. These were first, the gigantic bear-dogs, the direct ancestors of the bears, dogs in which size was at a premium and giantism seemed to be the goal of evolutionary progress. Secondly there were the hyaena-like or "hyaenognathid" dogs, which, though true canids through and through, imitated to some extent the hyaenas in their adaptations to life. Finally there were the two branches of dogs as we know them; on the one hand the hunting dogs of Africa and India, very much like the more familiar wolves



WOLF

and dogs but having a quite separate family history, and on the other hand the group of wolves, wild dogs and foxes, which may be considered as the central stem in this tree of canid history.

These were the particular specializations in the canid world. But throughout this melange of varying adaptations to different means of existence, there ran the central, unifying ties in the family history of the Canidae, like a strong warp weaving in and out among the varied threads of a patterned rug. These were: first, the universal adaptations among all of the canids toward a running mechanism of the body, capable of great speed; secondly, the attainment of a remarkably high degree of intelligence, commonly coupled with an extraordinarily well-developed sense of sociability; and lastly, the retention of a surprising amount of adaptability.

To continue our survey of the physical evolution among the dogs, the running habits so common to these animals must be stressed. The earliest dogs, such as *Cynodictis,* already showed some progress in this direction, although in these primitive forms the legs were relatively short as compared to the length of the body. But from the beginnings of canid history down to the point where man took a hand and produced specialized breeds, the story of evolution among these animals has been for the most part a tale of ever increasing limb length—a series of progressive adaptations for the running down and seizing of prey. In this respect the dogs differ from almost all of the other carnivorous mammals. The bears, their closest relatives, are huge lumbering creatures living for the most part on a diet of absurdly trifling items, and depending, when they do kill, on their great strength and size, while the raccoons, also close relatives, are primarily climbers. Of the other carnivores (except for the cheetah —an aberrant and quite uncat-like cat) only the hyaenas may be classified as primarily running animals. And the hyaenas do not rank at all with the canids when it comes to fast running—for they are not hunters but carrion feeders.

Thus we must think of the dogs—even the aberrant types that long since have become extinct—as the chasers of game, trailing their quarry mile after mile, hour after hour, until by the very diligence of their efforts and the cleverness of their methods they are able to overtake their prey. Of course, these remarks do not apply in their en-

tirety to all of the canids, but they outline the general rule for the adaptations in this family of carnivores.

"SOCIAL" INTELLIGENCE

The running adaptations in the canids have led to a method of life that has been very important in deciding the "social" life of these animals. For, early in the history of their development, these hunters must have discovered that it is much easier for a family to act together in running down a fleet victim than is such a feat for a single individual. Thus was born the habit of family hunting. And from this it was but a short step to the banding together of several families at advantageous times, to hunt as groups or packs.

Now this communal life, so characteristic of most of the dogs, led to the growth of sociability and a spirit of cooperation among the individual members of the group. Therefore, the dogs, instead of being individualists, such as the cats, became responsible members of a cooperative group, all working together toward a common end. Needless to say, animals living a life such as this are bound to exercise their intelligence to the utmost—they stimulate each other, and by working together they learn faster and build up the capabilities of their brains faster than would probably be the case if they were solitary.

Of course, generalizations such as these do not always hold. For among the canids, the foxes are strict individualists, and yet they are among the most gifted of the dog family, when it comes to a question of brains. Perhaps the answer is that the Miocene ancestors of the later canids were already extraordinarily intelligent animals, so that their descendants were bound to grow in wisdom, no matter what direction that growth followed. So it is that the foxes early in their history followed the solitary mode of life; but, living by their wits in much the same way that their wolf and wild-dog cousins lived, they naturally developed a sharp intellect. They became intelligent, as did all of the canids, because—among other things—of their heritage from precocious ancestors.

HUNTING BY RELAYS

It is interesting to notice a few of the means whereby this sociability is expressed. The tales of hunting by relays are so often told as to be almost trite. A number of wolves or wild dogs will map out a "course" over which the quarry is to be pursued. Then, several dogs will distribute themselves along this course—usually circular—and take their turns in chasing the antelope or deer, until the animal is fatigued to a point of exhaustion. In this manner it is relatively easy for several animals working together to accomplish their purpose with a minimum amount of effort on the part of the individual.

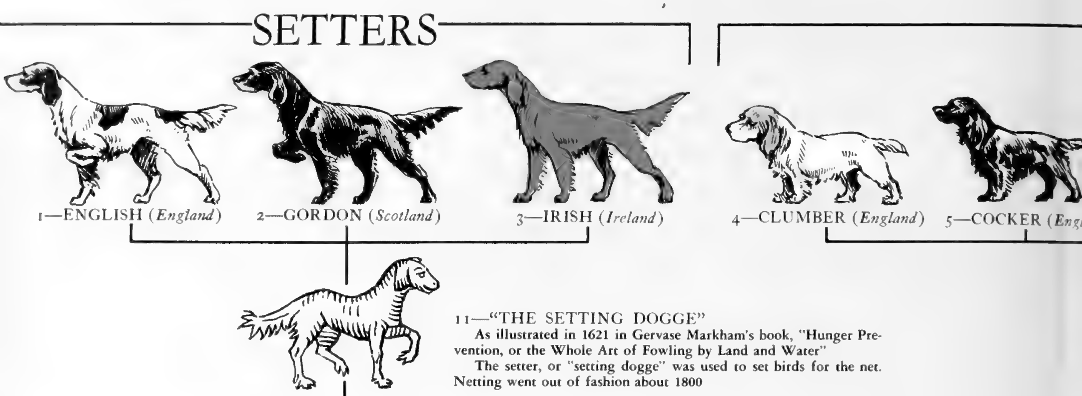
Indeed the spirit of cooperation is so highly developed within some of the canids that there are well authenticated records of wolves supplying food for an infirm and aged member of the pack.

One of the social habits of the wild dogs that is retained by their domestic relatives, is the rather annoying one (to us) of marking trees and posts with urine. I suppose that the average person gives but little thought to the origin of this habit, or its significance. Yet it is really quite a remarkable and characteristic adaptation among the Canidae, for it is a method whereby individuals are able to communicate with each other. The wolf has a series of bulletin boards scattered through his domain; these may be trees, rocks, bushes or other like objects. To these signposts he pays periodic visits, marking them to show other members of his group that he has been this way, and this is a part of his kingdom. And by sniffing at these posts he is able to determine what other wolves have been past in the last day or two, and whether or not they have had a right to be in his region. He learns whether the other visitors were male or female, young or old, well or ill, unworried or hunted. And through the use of these markers wolves seem to be able to spread the news of danger, so that when one animal is threatened, the entire community soon becomes aware of the threat. Thus an analysis of this habit shows that it is a highly developed trait among the canids, one in keeping with their sociability and their

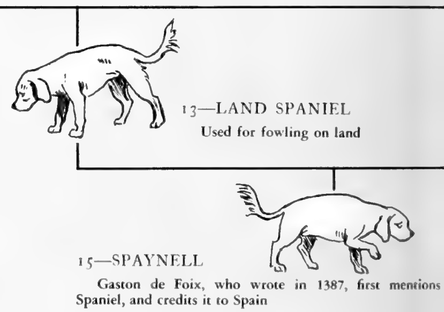
(*Continued on Page 14*)

One Hundred Aristocrats of the Dog World

THE DOG was probably the first ani[mal] domesticated by man, and the importanc[e of] his faithful help in the progress of the hu[man] race cannot be doubted. Much of his fa[r] history is lost in antiquity. It is known [from] archaeological evidence that man and [dog] worked together as long ago as 5000 to [...] B.C. in northern Europe, in the period [be]tween the Old Stone Age and the New S[tone] Age, and his history with man may be m[...]



GROUP I
SPORTING DOGS



About 1650 we find all dogs were divided in this manner:

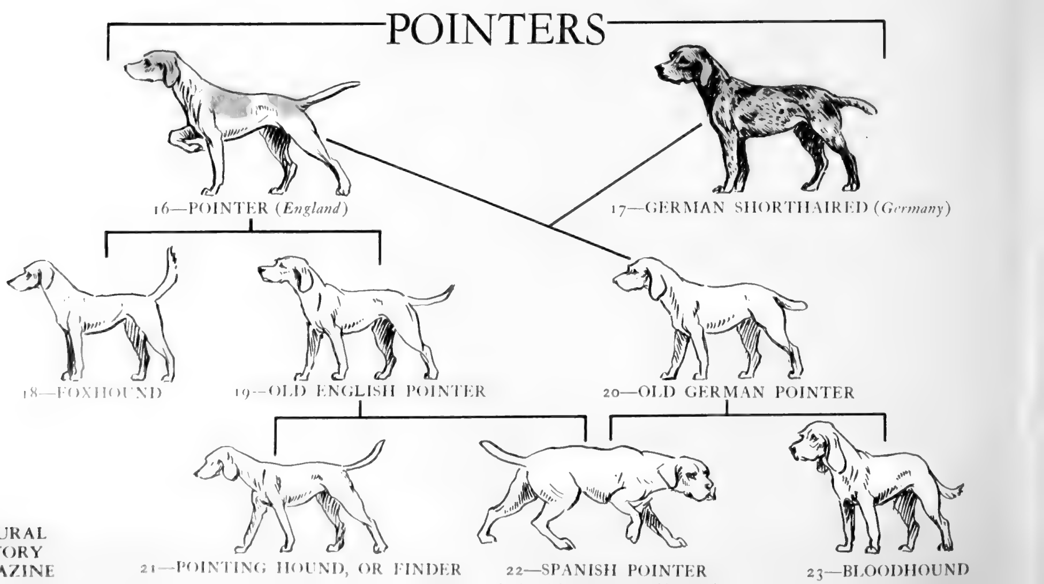
(1) Dogs used to find deer or other animals for the chase (Finder or Pointing Hound)

(2) Dogs used to spring feathered game for the hawk (Spaniels)

(3) Dogs used to set game for the net (Setters)

(4) Dogs used to retrieve wild fowl from the water (Water Spaniels)

Their further development as gun dogs has been in keeping with the development of the gun



older than that. But down to the time when "man's best friend" entered the pages of writ-en history his story must be pieced together argely by implication. We can know little of he breeds of dogs that may have vanished from the earth since the days of our primi-ive forebears, for from their bones it is diffi-ult to reconstruct the animal as he appeared n life and in many instances even to distin-guish him from the wolf. Likewise these charts do not attempt to describe the various distinct types of dogs that are identified with certain native tribes of the modern world. Historical records are the basis of this presentation, which portrays 100 of the most familiar dogs of today and gives the foremost authentic facts of their origin. The six-fold classification into Sporting Dogs, Hounds, Working Dogs, Terriers, Toy Dogs, and Non-Sporting Dogs is the one conventionally accepted by the Kennel Club of America and by dog breeders, but it does not imply that dogs in one group are necessarily closely related to each other. It is adopted here for the sake of convenience and because no genealogical chart has yet been worked out on anatomical and genetic evidence

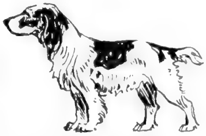
Compiled and drawn by

MORGAN STINEMETZ

SPANIELS


6—FIELD (*England*)


7—SUSSEX (*England*)


8—SPRINGER (*England*)


9—BRITTANY (*France*)


10—IRISH WATER (*Ireland*)

12—SPANIELL, OR "DOGGE FOR THE FALCON"

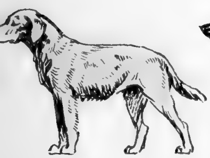
As pictured by Francis Barlow, 1626-1702. The Spaniell was used o flush pheasant, woodcock, etc., when hunting with falcons

Dr. Johannes Caius, the founder of Caius College, and court physi-cian to Queen Elizabeth, wrote the first book devoted exclusively to dogs, in 1570. In this book, "Of English Dogges", he divides the Spaniels as follows: "Ther be two sortes, the first findeth game on the land. The other findeth game on the water." He divides the land Spaniels again as the kind that "serve the hawk," and "seconde, the net, or traine"

14—WATER SPANIELL, OR FINDER

As illustrated in Markham's book, "Hunger Prevention, etc.," 1621. The dog was clipped to make swimming easier

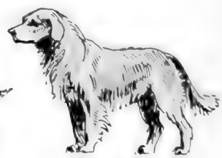
RETRIEVERS


24—CHESAPEAKE BAY RETRIEVER


25—CURLY COATED RETRIEVER


26—FLAT COATED RETRIEVER


27—LABRADOR RETRIEVER


28—GOLDEN RETRIEVER

The Retrievers form a distinct group, and with he exception of the Golden, all trace back to dogs from Newfoundland. How the original dogs got to Newfoundland is not known, but it is presumed hat they came as ships' dogs.

The generally accepted theory as to the origin of he Chesapeake Bay Retriever (24) is that he is descended from two dogs from Newfoundland rescued with the crew of an English brig wrecked off he Maryland coast. The American ship *Canton* made he rescue in 1807 and landed the English crew and he dogs on the shores of the Chesapeake Bay. The dogs were given to two gentlemen of that region in return for kindnesses to the crew. These two dogs, a male and a female, named "Sailor" and "Canton," made such great reputations as water-dogs and duck retrievers, that they were mated with nondescript dogs of the neighborhood which were used for the same work. Whether they were ever mated together, s not known.

The connection of the Curly Coated (25), Flat Coated (26), and Labrador Retrievers (27) to the Newfoundland is through a dog known as the St. Johns Newfoundland. These dogs were first brought to England in 1835 by vessels carrying salt cod from Newfoundland. Early writers often referred to them as Labradors. This has caused some confusion, as others claim that the original Labrador was a different dog altogether from the St. Johns Newfoundland, but brought to England about the same time from Newfoundland.

It is believed that the Curly Coated Retrievers were produced by crossing the St. Johns Newfoundland with descendants of the Old English Water Spaniel (a breed known to have existed in England as early as the 16th century) and the retrieving setter. At a later date, the Poodle was used as a cross to improve the curl of the coat.

The St. Johns Newfoundland and the original Labrador, (possibly variations of the same breed) are claimed as the foundation cross for the Flat Coated Retrievers. Added to this, at later dates, were both Gordon and Irish Setter crosses.

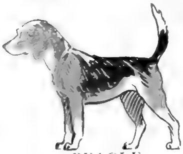
The modern Labrador Retriever is claimed to be the product of the cross between the St. Johns Newfoundland and the original Labrador. He is also claimed to be the original St. Johns Newfoundland. Although there is some doubt as to the real origin of these dogs, there can be little doubt that the dogs from Newfoundland helped materially in producing these natural water-dogs.

The Golden Retriever (28) springs from an entirely different line from the other retrievers. He is the descendant of an old breed known as the Russian Tracker. The Tracker first came to England in 1860 and was kept in its original state until 1870. In that year, one cross was made with the Bloodhound to reduce the size. The Tracker was a larger dog than his descendant, otherwise, they are practically the same.

d and drawn by
S. STINEMETZ

GROUP II

SCENT HOUNDS



29—BEAGLE
(*England*)

Origin of these hounds is lost in antiquity. The Beagle, smallest of trailing hounds, was known in England as early as 1560. Basically its stock is that of the Harrier and Foxhound

30—HARRIER
(*England*)

This name designated all hounds before pains were taken to breed them solely for fox hunting; assumption being that modern Harriers derive from Foxhounds. The first pack of Harriers formed in 1260 was maintained for 500 years

31—FOXHOUND
(*England*)

The first mention of Foxhounds was in 1735 in The Sportsman's Dictionary. By the beginning of the 19th century, type was well established and packs were numerous

32—BASSET HOUND
(*France*)

33—BLOODHOUND
(*England*)

Traditionally of French origin, the Basset really traces to the East. Descendants of the St. Hubert hounds (bred by St. Hubert Abbots since 6th century), they came originally from Constantinople. Kin to the Basset, the Bloodhound was developed in England through crossing St. Huberts with eastern hounds brought home by returning Crusaders. So sure is the Bloodhound's scent, he is the only dog whose evidence is accepted in court

GROUP III WORKING DOGS

This general-purpose group is made up of dogs kept and bred for specific uses other than field sports. The accurate known history of most of these breeds does not extend much beyond the date of the first dog show, which was held in England in 1859. The early breeders of these dogs kept no records. They were interested primarily in the dogs' abilities, therefore mated only those dogs having the desired abilities in the highest degree. Eventually, in various localities, they became recognizable as distinct breeds with a highly developed sense for performing certain duties. Their refinement in conformation came at a later date with the beginning of dog shows

There are two distinct types of this small cattle dog. Both claim ancient ancestry. It is claimed that the Cardigan, with the crooked legs and long tail, was brought to Cardiganshire by the Celts in 1200 B.C.; while the Pembroke, with the straight legs and naturally short tail is said to have come with the Flemish weavers to Pembrokeshire in 1107 A.D. The Pembroke carries a trace of the Cardigan blood due to crosses made about the middle of the 19th century. The Cardigan in turn, carries a slight infusion of the blood of an old type of dog known as the Brindle Herder

39—WELSH CORGIS, PEMBROKE (*Wales*)

40—WELSH CORGIS, CARDIGAN (*Wales*)

SLED DOGS

46—ALASKAN MALAMUTE
(*Alaska*)

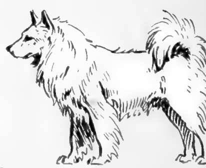
Alaskan Sledge Dog (now Malamute, from the Mahlemute Eskimo tribe) was found in Alaska by Russians long prior to U. S. purchase. Development of a pure strain dates only from 1926. This breed was used on two Byrd Expeditions

47—ESKIMO
(*Alaska to Greenland*)

The Eskimo dog probably originated in Eastern Siberia. They were taken by the Eskimos to Alaska, Northern Canada, Baffin Land, Labrador, and Greenland. They were used by Peary and Amundsen on Arctic and Antarctic expeditions

48—SIBERIAN HUSKIE
(*Siberia*)

The Siberian Huskie has been bred true to type in northeastern Siberia as long as earliest inhabitants can recall. He was first brought to Alaska (1904) as contestant in the 408-mile non-stop All-Alaska sweepstakes



49—SAMOYEDE
(*Siberia*)

Samoyedes have been bred for centuries by the Samoyed people. Introduced into England less than 100 years ago, they were used by both Shackleton and Scott on various expeditions

SHEEP DOGS

55—SHETLAND SHEEPDOG
(*Shetland Islands*)

Actual origin of the Shetland Sheepdog is obliterated by lack of records. Tradition declares them as old as Scotch Collies which came to the Shetland Islands, to become their probable sires

56—COLLIE
(*Scotland*)

The Collie, now beautified by breeding, has a cloudy origin, but his shepherd history is long. First shown in England in 1860, his U. S. popularity came later, though a few work collies were probably imported by colonials

57—BELGIAN SHEEPDOG
(*Belgium*)

Related to a number of Central European herders, the Belgian Sheepdog has two recognized varieties, the one shown (Groenendael) being the more important. The other (Malinois) differs in coat only. Both used in police work

58—GERMAN SHEPHERD DOG (*Germany*)

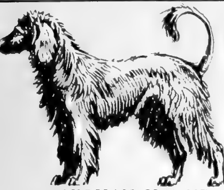
The German Shepherd Dog is derived from old breeds of herding and farm dogs, and has been intensely developed in the last 45 years. It is widely used in police work

59—BRIARD
(*France*)

The Briard, an outstanding sheepdog, is recorded as far back as the 12th and accurately described in the 14th and 16th centuries. He belongs to a very ancient French strain

HOUNDS

SIGHT HOUNDS



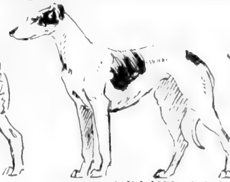
34—AFGHAN HOUND
(*Asia*)

e modern history of the Afghan Hound es from the World War, when dogs re brought back to England by return- British officers. Its history goes back ancient Egypt. How it got to Afghanis- is not known

35—SALUKI
(*Asia*)

36—BORZOI
(*Russia*)

Carvings in Egyptian tombs support claims that the Saluki (Persian Gazelle Hound) is the oldest known domestic dog. First entering England (1840), they made little headway until imported from Arabia (1895). One of Borzoi's ancestors, the Saluki, came to Russia to slake a noble's thirst for fast dogs(mid 17th century). To get needed fur it was crossed with a collie-like native. Result: the Borzoi, well defined by 1750, in sketches of that period



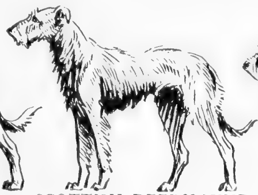
37—GREYHOUND
(*England*)

38—WHIPPET
(*England*)

Though owing its modern development to England, the Greyhound can be traced back as far as we have any delineations of dogs. Always bred for speed, it was the first dog to be bred to shape, and the first rules for coursing with Greyhounds were drawn up at the request of Queen Elizabeth. The Whippet, "digest-sized" greyhound, was produced around 85 years ago by North England miners from greyhound and various terrier crossings, and later the small Italian Greyhound. He is called "the poor man's race horse"

—IRISH WOLFHOUND
(*Ireland*)

e modern Irish Wolfhound dates y from 1862. That year, the ient semi-legendary strain's few vivors were bred with Scotch deer- nds. Later, the Great Dane and zoi were admixed



42—SCOTTISH DEERHOUND
(*Scotland*)

Probably the longest preserved of the original hunters. Though stemming from Irish wolfhounds, the longevity of hounding deer, as against wolves, kept up the breed's general form despite the deer's speed requiring a lighter, racier dog

43—OTTER HOUND
(*England*)

The Otter Hound, first described in the early 14th century as a "rough sort of dog, between a hound and a terrier," did not make its appearance in the U. S. until the 20th century. First exhibited, 1907

44—NORWEGIAN ELKHOUND (*Norway*)

Known for extraordinary scenting abilities, the Norwegian Elkhound's ancestral claims trace back to the time of the Vikings, or earlier. Refinement of the breed began after 1877

45—DACHSHUNDE
(*Germany*)

Although recognized as essentially a dog of Germany, there can be no doubt that the Dachshunde was found throughout Western Europe at an early date. Official breeding data go back to 1840

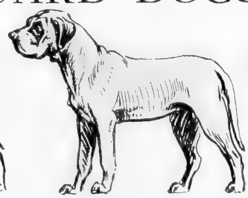
GUARD DOGS

50—DOBERMANN PINSCHER (*Germany*)

eveloped in the last 45 years, e Dobermann traditionally ems from Black and Tan errier, Old German Pinscher d Smooth-coated Shepherd, ottweiler, possibly others. Videly used in police work

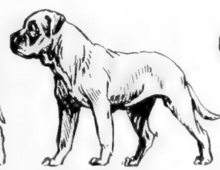
51—GREAT DANE
(*Germany*)

Natively German, the Great Dane has apparently no connection with Denmark. Strongest indication seems to point to the Mastin (big medieval European hunter) as his ancestor



52—MASTIFF
(*England*)

The term mastiff originally described a large group of dogs. The Mastiff of today belonged to this group, and it is claimed he was found in Britain by the Romans in 55 B.C.



53—BULL MASTIFF
(*England*)

About 80 years ago begins the Bull Mastiff's known history; gamekeepers then crossed the Bulldog and the Mastiff to secure a fearsome aid in their continual warfare with poachers

54—BOXER
(*Germany*)

The Boxer owes his perfection to Germany. He was developed within the last 100 years from dogs of this type known throughout Europe for centuries

MISCELLANEOUS

60—OLD ENGLISH SHEEPDOG (*England*)

ere is no definite information ut Old English Sheepdogs before early 19th century. They were de- oped in the west counties of En- nd as a "drover's dog." Many are n tailless

61—NEWFOUNDLAND
(*Newfoundland*)

The Newfoundland originated in Newfoundland from ancestors taken there as ships' dogs by European fishermen. The breed was developed in England during the last century

62—ST. BERNARD
(*Switzerland*)

Records of the St. Bernard date from 1707, at which time, however, it had already earned a reputation for rescue work. It was 1880 before the name St. Bernard was officially designated, though it had been in common use for some time

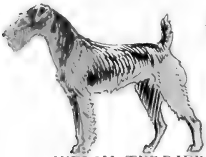
63—GIANT SCHNAUZER
(*Germany*)

First used as a drover's dog, the Giant Schnauzer came of crosses between the standard Schnauzer, herd dogs of South Germany, and later, the Great Dane. Practically unknown outside of Bavaria until 1910, it was introduced to the U. S. only about a dozen years ago

r, any dog small and game enough t game and vermin in its burrow was ed a terrier. From this common material e present terriers have developed. Though differing in type, they all have the same character—hard-biting, courageous dogs, small enough to go to earth. With two exceptions, they are distinctly a product of the British Isles

GROUP IV—TERRIERS

Compiled and drawn by
MORGAN STINEMETZ



64—WELSH TERRIER
(*Wales*)

Not Welsh, this terrier springs from the old English Wire-haired Black and Tan (oldest known English terrier) and was so called until 1887. It was first brought to the U. S. in 1888

65—MANCHESTER TERRIER
(*England*)

The original smooth-coated Black and Tan Terrier, described over 125 years ago, crossed with the Whippet, produced the modern Manchester. It was called the Black and Tan Terrier until 1923, when, because of its development and popularity in the Manchester district, it became, officially, "Manchester"

66—FOX TERRIER, SMOOTH (*England*)

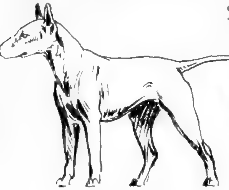
The progenitor of the breed seems to have been Col. Thornton's "Pitch," a dog well-authenticated in a picture painted by Gilpin in 1790, and thought to be the result of mating a small greyhound and an Old English Terrier

67—FOX TERRIER, WIRE (*England*)

The Wire (called Wire-haired Terrier until 1882) stems from the old English Broken-haired Black and Tan Terrier. Liberal crossing with smooth Fox Terrier brought the predominating white coat

68—AIREDALE TERRIE
(*England*)

The Yorkshiremen in th neighborhood of the rive Aire developed this hunting terrier from a cross of the ol English Broken-haired Terrie with the Otterhound



69—BULL TERRIER
(*England*)

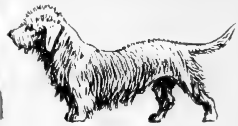
As the name implies, this terrier is the result of a cross made about 100 years ago between the Bulldog and the Old English White Terrier (now extinct). The blood of the Spanish Pointer was added at a later date

70—NORWICH TERRIER
(*England*)

This dog is a newcomer to the U. S. but has been known in England since 1880. There is no definite information as to its origin

71—BORDER TERRIER (*England*)

The Cheviot Hills, which form the Border country, holds the secret of the origin of this little terrier. The breed has been carefully preserved by Border farmers for many generations

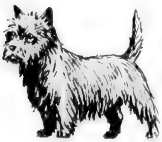


72—DANDIE DINMONT TERRIER (*England*)

Originating in the Cheviot Hills, this terrier was recorded as early as 1700. The name comes from Sir Walter Scott's "Dandie Dinmont," the farmer in *Guy Mannering*, who owned six of these terriers

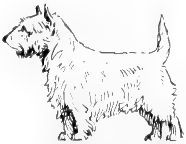
73—BEDLINGTON TERRI
(*England*)

This terrier originated in the county of Northumberland well over 100 years ago. He possesses certain characteristics—the top-knot and the long drop ears—peculiar to only one other terrier, the Dandie Dinmont



74—CAIRN TERRIER
(*Scotland*)

The prototype of the modern Cairn was the old working terrier of the West Highlands and the Isle of Skye. The short legs are characteristic of all the terriers of Scotland



75—WEST HIGHLAND WHITE TERRIER (*Scotland*)

The breed originated at Poltallock, Scotland, well over 100 years ago. It is probable that it is of the same basic stock as the Cairns and the Scottish Terrier

76—SCOTTISH TERRIER
(*Scotland*)

The first Scottish Terriers were exhibited in 1860. Though well established as a breed at that time, there is practically no definite information regarding them before that date

77—SKYE TERRIER
(*Scotland*)

An old breed from the Isle of Skye which was accurately described in 1570 in the first book devoted solely to dogs, "English Dogges," by Dr. Caius, court physician to Queen Elizabeth

78—SEALYHAM TERRIE
(*Wales*)

The Sealyham takes its name from an estate in Wales, where between the years 1850 and 1891 the breed was developed by Capt. John Edwards from dogs of obscure ancestry. First appearance in a dog show was in 1903

79—IRISH TERRIERS
(*Ireland*)

Irish Terriers were first exhibited in 1879. Aside from the fact that they came from the north of Ireland, their early history is only speculation

80—KERRY BLUE TERRIERS
(*Ireland*)

The national dog of the Irish Republic. Originating in the County Kerry, the Kerry Blue Terrier is claimed to have been pure bred for 100 years. They were first exhibited in the U. S. in 1922

81—SCHNAUZERS
(*Germany*)

This dog bears no relationship to the British Terriers. He is classed as a terrier in this country, but not so in Germany, where he originated, probably from crosses of the Poodle, with Wolf Grey Spitz and Old Pinscher stock

GROUP V—TOY DOGS

2—PEKINGESE (*China*)

le traces to the 8th cenury Tang Dynasty. First f these dogs to reach ngland were four taken om the looted Imperial alace in Peking (1860)

83—JAPANESE SPANIEL (*Japan*)

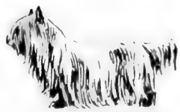
Allegedly very old, its actual record dates from Commodore Perry's expedition (1852-54) and delivery of four of the dogs, the Emperor's gift, to President Pierce

84—ENGLISH TOY SPANIEL (*England*)

Descended from the "Spaniell Gentle, otherwise called the Comforter," according to Dr. Caius (1570). Credited with a Chinese origin

85—MALTESE (*Malta*)

One of the oldest known breeds, Dr. Caius (1570) wrote of them: "That kind is very small indeed, and chiefly sought after for the pleasure and amusement of women"

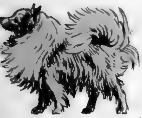


86—YORKSHIRE TERRIERS (*England*)

Developed in Yorkshire and Lancastershire, there is no information on origin of this breed. First showing: England (1861) as "Scotch Terrier." Introduced here about 1880

87—TOY POODLES

Today's breed springs from the larger Poodles. That the popular 18th century "White Cuban" came from Cuba is doubtful. But his true "birthplace" is an enigma



8—POMERANIANS (*Germany*)

Developed in Pomerania, rom old Spitz stock at n unknown date, the reed was not wellnown in England until 870. It was first exhibted in the U. S. in 1892

89—PAPILLON (*Spain*)

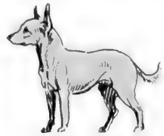
Developed from the "dwarf spaniel" (dating from 16th century), these little dogs, favorites of Mme. de Pompadour and Marie Antoinette, were painted by Watteau, Fragonard, and Boucher

90—GRIFFON (*Belgium*)

Descended from the small Belgian street dog and the Affenpinscher, it was unknown until 1895 outside Belgium. Some say both Pug and English Toy Spaniel influenced this development

91—PUG (*China*)

Its popularity there plus its introduction to England by the Dutch East India Company, have often given Holland credit for the origin of the Pug. China seems more likely



92—CHIHUAHUA (*Mexico*)

The known history of the Chihuahua begins about 1850, when specimens of the breed were found in the state of Chihuahua. Believed to be a descendant of the Techichi, a dog of the Toltecs

93—MEXICAN HAIRLESS (*Mexico*)

Contrary to general belief, Mexico is not alone in having a native hairless breed. The Mexican Hairless strongly resembles a Chinese hairless breed

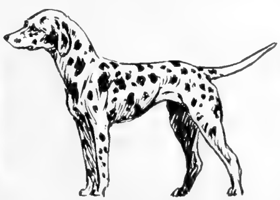
GROUP VI—NON-SPORTING DOGS

94—POODLE

Though popularly regarded as a dog of France, the Poodle is believed to be of German origin. The clipped Water Dogge shown in the first group (14) bears a striking resemblance to the Poodle and is thought to be one of his ancestors. Where the custom of clipping poodles originated is not known

95—CHOW CHOW (*China*)

The marked peculiarity of having a blue-black tongue distinguishes this ancient Chinese breed from all other dogs. First English description given in the Rev. Gilbert White's *Natural History of Selborne*, tells of a pair brought from Canton by a neighbor in 1780. Finally popular in England by 1880, it was first exhibited ten years later in the U. S.



96—DALMATIAN (*Dalmatia*)

There is very little information as to the Dalmatian's lineage, but he is believed to have descended from the same class of hound as the pointer. Old pictures and engravings depict the Dalmatian very nearly as he is today

97—BULLDOG (*England*)

The Bulldog is entirely British in his origin and development. By careful selection, the modern dog has been developed from the dog used for the once popular sport of bull-baiting. As we know him today, the Bulldog bears little resemblance to his ancestor, and has none of his viciousness

98—BOSTON TERRIER (*United States*)

The Boston Terrier is an American product, named after the city of its origin. The crossing of a Bulldog and a white English Terrier about 60 years ago is claimed to have started this breed. Inbreeding and careful selection have made him what he is today

99—FRENCH BULLDOG (*France*)

Several varieties of the small, or toy Bulldog bred in England around 1860, were exported liberally to France. It is generally conceded that these dogs, crossed with other breeds, evolved the French Bulldog. There is little accurate information

100—SCHIPPERKE (*Belgium*)

Although known to have originated in Belgium's Flemish provinces, little accurate knowledge and considerable difference of opinion have characterized investigations of this breed. Prior to 1888, they were called Spits or Spitske. This country first saw them in 1885

(*Continued from Page 7*)
gregariousness, and one that is of the utmost importance in the scheme of their lives.

Examples might be multiplied *ad infinitum,* but perhaps these are enough to demonstrate the rare combination of mental acuteness and cooperation typical of the wild dogs.

It is very difficult, and more than a little bit risky, to dogmatize as to the ranking in intelligence among the mammals, but certainly it is safe to say that the canids are among the most intelligent of the warm-blooded animals. In a large part this intelligence is innate, just as it is among all of the carnivorous mammals. But it is quite definitely augmented by the sociability of the dogs and their relatives, thereby making a combination of qualities that particularly suit these animals to live commensally with another intelligent species—Man.

Then, there is the remarkable adaptability of the canids, a trait that has been of immeasurable worth in enabling them to become suited to their surroundings. Structurally the canids are not highly specialized. Except for their long legs and compact feet as adaptations to running, and their highly developed brains, they are on the whole rather generalized carnivores. Hence they are unusually plastic, both physically and psychically, and are able to adapt themselves readily to changing conditions.

Contrast, if you will, the numerous types of wild canids with the cats. Cats, whether they be small or large, are generally speaking of one pattern, for these animals became highly specialized early in their phylogenetic history, and have been rigidly fixed ever since. Consequently a tiger and a puma and a house cat are much the same, except as to color and size, whereas the canids in their wild state show a rather wide range of adaptive radiation. This plasticity among the canids is illustrated artificially but none the less effectively by the extraordinarily numerous breeds of the domestic dogs, showing a range in size between the Chihuahua and the Great Dane and a range in form between the bulldog and the greyhound. What a contrast these artificial adaptations among the domestic dogs afford, as compared with fixity of the domestic cats.

But this plasticity in the canids is not confined to physical make-up alone, for these animals—at least the gregarious canids—are remarkably adaptable in their mentality. It is this fact that has made the dogs so amenable to domestication; the dog has been domesticated because he has been willing to conform to the ways of man, not only in his habits but even in his manner of thinking.

To thoroughly appreciate and really understand the domestic dog, it is necessary to become acquainted with his heritage from numerous ancestors, running back in an unbroken line for many millions of years, and to keep in mind the many ties that bind him to his wild relatives of the present day. When we take this comprehensive view of the dogs as we know them, we get an inkling of the various factors of heredity, environment and behavior that have worked together to bring about that combination of characters and traits which we recognize as being typical of the Canidae. Thus we see that the dogs are members of a varied and a highly interesting family of carnivorous mammals—a family of swift runners, characterized by the attainment of a high degree of intelligence, by a general feeling of sociability, and by a trait of adaptability that has enabled them to adjust themselves to a rapidly changing environment. Is it any wonder, then, that they should be the first animals to fall under the all-pervading influence of Man?

MAN AND NATURE
PUBLICATIONS

REPRINTED FROM *NATURAL HISTORY*
VOL. XLIII, NO. 2 FEBRUARY, 1939

THE AMERICAN MUSEUM OF NATURAL HISTORY
NEW YORK 24, N. Y.

THE HISTORY OF THE VALLEY OF MEXICO

AN ILLUSTRATED CHART

A SUPPLEMENT TO SCIENCE GUIDE NO. 88
ARTISTS AND CRAFTSMEN OF ANCIENT CENTRAL AMERICA

By GEORGE C. VAILLANT

Science Guide No. 103

REPRINTED FROM *NATURAL HISTORY*, VOL. XXXVIII, NO. 4

NEW YORK 24, NEW YORK
The American Museum of Natural History
1946

The History of the Valley of Mexico
Panel I
Archaic Culture
Panel II
Toltec Civilization
(about 500-1100 A.D.)
Panel III
The Chichimec Period
(1100-1325 A.D.)
Panel IV
Aztec Period

MAN AND NATURE
PUBLICATIONS

PEARL DIVERS

By Roy Waldo Miner

Science Guide No. 104

REPRINTED FROM
NATURAL HISTORY
OF MAY, 1941

PEARL DIVERS

By Roy Waldo Miner
Curator Emeritus of Invertebrates

Science Guide No. 104

NEW YORK CITY
The American Museum of Natural History
1946

THIS *Tridacna* CLAM, adorned with a fragile living coral, grew on the lagoon floor, 25 feet below the surface. The photograph represents the animal modeled in wax within the actual shells so as to display its gorgeously colored mantle edges, which, in life, expand over the scalloped shell margins

PEARL DIVERS

BY Roy Waldo Miner

Curator Emeritus
of Invertebrates
The American Museum
of Natural History

An account of an American Museum expedition to the South Pacific to obtain material and data for a new group in the Hall of Ocean Life depicting the undersea activities of the Polynesian natives in their traditional search for the treasures of the deep.

THE ZACA was lying at anchor off Penrhyn Island, called Tongareva by its native inhabitants. A stiff breeze, blowing over the land from the east, raised dancing multitudes of whitecaps, their snowy crests contrasting strongly with the deep ultramarine of the tropic sea. The white strand of the distant shore, disappearing and appearing alternately as the foaming breakers dashed against it, was crowned with long lines of coconut palms tossing their green plumage as the trade wind swept over them. Midway, their verdant line was broken by two shelving points, bare and rock-strewn, that seemed nearly to meet on either side of the narrow West Pass, the only practicable entrance for our vessel to the sheltered lagoon of the coral atoll.

As we watched, a sail appeared in the opening, delicately threading the tortuous channel, and headed for the open sea. It was followed by another and another, and finally a multitude of craft, obviously smaller than the leading vessel, emerged from the opening and shaped their course directly toward us before the wind.

Examing them through our glasses, we saw that the larger boat was a sloop, flying the blue of the British colonial ensign, and realized that we were to recieve an official call from the Government Agent in charge of the island. As the fleet drew nearer, we made out that the smaller vessels were numerous out-rigger canoes, their single sails manipulated skillfully by their Polynesian navigators. Soon they arrived alongside, and, as the Agent, Philip Woonton, came aboard, the owner of the *Zaca* and sponsor of our expedition, Mr. Templeton Crocker, met him at the gangway and escorted him aft to meet us. Almost immediately, the dusky-skinned natives swarmed over the gunwales, examining the vessel and fraternizing with the sailors forward.

Philip Woonton, clad simply in jersey and white trousers, with a native broad-brimmed straw hat shading his swarthy face, greeted us hospitably. Mr. Crocker handed him our credentials, including a letter of introduction from our friend, Dr. Peter Buck, the Director of the Bishop Museum of Honolulu, who had previously spent much time on the island studying its inhabitants, and had established most cordial friend-

FRANK TIAGA, Samoan sailor from the *Zaca*, equipped with water-tight goggles, diving for corals. Through his efforts many of our finest specimens were secured, including the great 900-pound coral shown on page 13

(*Left*) The graceful power-schooner, *Zaca*, which carried our expedition to the South Seas, riding at anchor outside the atoll of Tongareva, while waiting for a native pilot

(*Right*) The *Spray*, official boat of the British Government Agent, Philip Woonton, emerges from the Tongareva lagoon to welcome the expedition to the island

Photos by Roy Waldo Miner

(*Below*) The *Zaca* under way toward the West Pass, the difficult lagoon entrance, guided by a skillful native pilot. Mr. Crocker, Mr. Woonton (in broad-brimmed hat), and other members of the Museum party are standing near the after rail

Photo by Toshio Asaeda

(*Left*) Native outrigger canoes being towed astern as seen from the masthead. Their native crews are aboard the *Zaca* curiously examining the vessel and fraternizing with the sailors forward

(*Above*) The native village of Omoka nestles beneath groves of coconut trees on a point of land inside the circle of the lagoon. The *Zaca* came to anchor beyond this point

(*Left*) The narrow native canoes are made from scooped-out tree trunks with plank gunwales fastened on by twisted cords of coconut fiber. Outriggers keep them from capsizing when under sail

Photos by Roy Waldo Miner

(*Above*) Native boys, supported by half submerged branches of trees, swam around the *Zaca* for hours, curiously watching our movements

(*Below*) Tongarevans cleaving coconuts on sharpened stakes. The coconut meat is dried to make copra and sold to passing trading schooners. It is eventually used for making confectionery and soap

(*Below*) The dense groves of coconuts furnish the natives with all the necessities of life, including food, drink, clothes, and housing

ship with him. This settled the matter and we were informed that the entire island and its inhabitants were at our disposal.

When Mr. Woonton learned that the purpose of the expedition was to make a study of the pearl oysters, which, Dr. Buck had said, abounded in the lagoon, with the view to building a group in the American Museum representing the native divers in the act of gathering them, he became quite enthusiatic and assured us of every assistance in his power.

His most experienced native pilot was then called aft to the wheel, and soon our engines were driving the *Zaca* against the wind toward the narrow entrance, towing behind us Mr. Woonton's boat, as well as a long line of the native dugouts, attached tandem fashion to our stern.

A NARROW OPENING

Very shortly, we were tossing in the midst of a swirl of conflicting currents and foaming whitecaps, as we negotiated the narrow and perilous entrance channel, and then, suddenly, we were quitely riding in the calm turquoise waters of the lagoon. Under the guidance of our pilot, we skirted the luxuriantly green inner shore, rounded a point of land, and soon were floating at the anchorage assigned to us. Opposite lay the picturesque little native village of Omoka, with its simple dwellings nestling under dense groves of coconuts that seemed to crowd every inch of available space. As soon as we had rounded the point, all the inhabitants, men, women, and children, came crowding down to the shore and even invaded the water, paddling around us in their canoes or bobbing about the boat as they swam as near as they dared—for Woonton had warned them to keep at a respectful distance.

Tongareva is a typical atoll, or ring-shaped island of coral, surrounding a central lagoon, one of many such beautiful formations in the South Pacific Ocean. It forms a large oval, eleven miles through its greatest diameter, composed of a series of long, narrow islets, called *motus*, connected by streches of coral reef, awash at low tide, and absolutely impassable for boats. The waves of the open sea dash against the outside of these reefs with considerable violence, rushing into the lagoon at high water.

Coral atolls are usually most accesible on their western side, many of them having but this one entrance. Some, however, are completely landlocked, with lagoons that can be navigated only by small boats or canoes carried across the barrier by hand.

All the *motus* of Tongareva are covered with dense growths of tropical vegetation, mostly coconuts. The plantations are almost over-dense for the natives refuse to thin them out, believing that the value of their land depends on the number of coconuts growing on it. These remarkable trees do not have to be cultivated, as they spring up without any trouble on the part of the inhabitants. They furnish the natives with the material for houses, clothing, mats, cordage, fish nets, food and drink, so they cannot be blamed for considering them as the foundation of their well-being. In fact, the coconuts have also brought the Pacific Islanders a measure of prosperity. For they dry the meat of the nuts to make copra. This is exported in large quantities for the manufacture of soap. The lagoon abounds in tropical fish of all kinds, which form additional food resources, as the islanders are expert fishermen. Finally, Tongareva, like many other Pacific islands, produces the precious pearl oyster, the iridescent shell of which secretes mother-of-pearl and is sold by the ton to trading schooners, to be used for knife-handles, inlays, and pearl buttons. Occasionally, a shell is found which yields a precious pearl, often of great value, enriching the finder, the middleman, and the merchant. As we have said, it was to study these pearl oysters in their native environment that we came to Tongareva.

We found the Tongarevans intelligent and co-operative. They are of the Polynesian race, said, with good scientific authority, to show certain Caucasian traits, doubtless having spread hundreds of years ago into the Pacific Islands from southeastern Asia. There were between 450 and 500 native inhabitants on the island at the time of our visit, mostly living in two villages at opposite ends of the lagoon, known as Omoka and Tetautua, respectively.

EXPLORING THE BOTTOM

Mr. Woonton assigned two natives to us,—Tau, who was the "policeman" of the village, and Toni, a young boy. Both were excellent swimmers and divers, and Tau, particularly, knew all the reefs and shoals intimately.

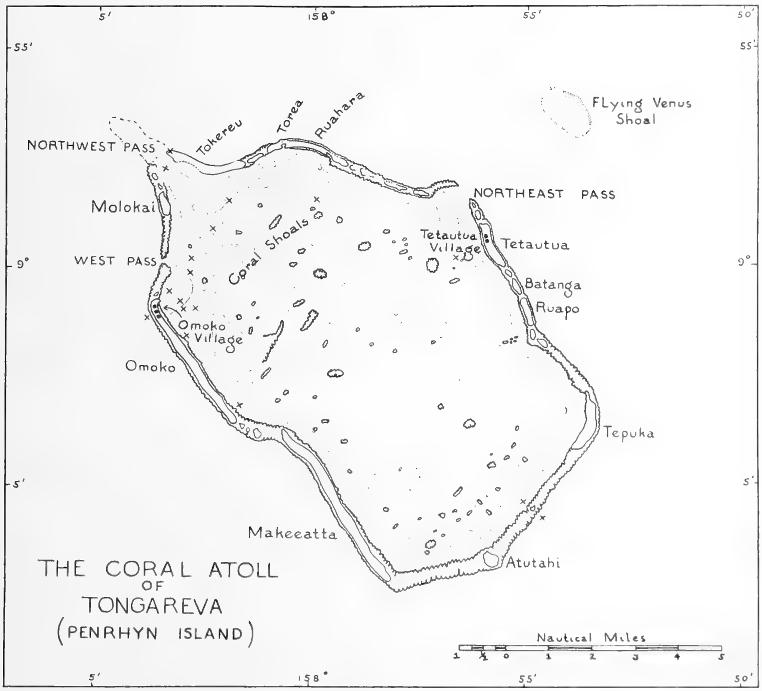
Under his guidance we spent the first two or three days exploring the region in one of the *Zaca's* launches, especially around the coral shoals in the western part of the enclosed lagoon. The waters were very clear, and, using waterglasses (buckets with a glass bottom), we could see the sea floor very clearly for 60 feet or more, and thus were able to pick out the best localities for our undersea investigations. On the third day after our arrival, we were all ready and had our equipment put in order for the work. We then started in earnest and, as we had good weather, we kept on for nine days without a break.

Our method was as follows. Two boats belonging to the *Zara* were put at our disposal. One of these, an "otter boat," was a small and handy motor launch; the other was a dory. The otter boat carried our photographic equipment,—cameras, undersea camera boxes, and photographic films—, in charge of René, the radioman. Also, Toshio Asaeda, the Japanese artist and photographer of the *Zaca*, was installed here with his sketch blocks and colors, with John, the first mate, as navigator. The dory was reserved for the diving equipment. In it were the two diving helmets with their pumps and hose; the special undersea camera tripods and the hand nets; also, the "bang-bang" (to be explained later), the waterglasses, and the brass-rope ladder. Betts, Olsen, and I occupied this boat with the two sailors who were to man the pumps.

We arrived at our location alongside one of the many shoals. These are interesting growths of living coral composed of many species which, by their combined activity, had grown up from the lagoon bottom, at first as clustered pinnacles, then as broadening columns, which spread out their flat, mesa-like tops within a foot or two of the water surface. The top and sides of these castle-like limestone structures are made up of fragile branching colonies and massive domes of living coral of soft contrasting colors.

The anchors of the dory were thrown out across the top of one of these shoals, thus securing it fore and aft. The otter boat was then lashed parallel to the dory on its outer side. The brass-rope ladder, with rungs one foot apart, was unrolled over the gunwale, to which it was fastened at the top, the lower end trailing over the sea floor 20 or 25 feet below. I was always the first to go down. I stood on the ladder, submerged to my shoulders, while the diving helmet was lowered over my head. The pump was started, and when I felt the stream of fresh air entering the helmet and the comforting clank of the pump beat near my ear, I descended the ladder. Immediately, the 65-pound helmet completely lost its weight as it submerged, and I myself seemed as light as a feather. I climbed down, rung after rung, swallowing as I went to relieve the increasing pressure against the eardrums, and stepped off on the sandy sea floor from the twenty-fifth rung, thus measuring my depth from the surface as 25 feet.

I turned from the ladder and saw before me the precipitous side of the shoal, rising above me in terraces, with overhanging growths of fantastic shapes, adorned with the most beautiful corals imaginable in rich purples, blue, browns, saffron orange and green. Their shapes varied from huge rounded domes to the most delicate lacework, interspersed with contorted finger-like lobes, gathered in clusters of rich rose. Round about me and above my head flitted fishes of the most gorgeous and weird combinations of color and form, many of them reflecting the sunlight like jewels of coruscating brilliancy and changing prismatic hues. The immediate neighborhood was as transparent as air. I could see fully 100 feet in all directions before the gathering luminous blue fog of the watery distance limited my vision. The under-surface of the water above me gleamed with silver, reflecting like a mirror when quiet, and changing into dancing quicksilver when a breeze threw the surface into ripples and waves.



THIS TYPICAL ATOLL, 2000 miles directly south of Hawaii, is made up of islets connected by half submerged coral reefs, surrounding an eleven-mile lagoon. The crosses mark the coral shoals where the Museum's undersea studies were made

Photo by Roy Waldo Miner

The brawny arms and magnificent chest muscles of Frank, the Samoan sailor, were always at our disposal for sculling our boats and diving for coral specimens, many of which were huge masses dislodged only with great difficulty

Photo by Wyllys R. Betts

Frank's favorite tool was the conventional carpenter's ripping bar, which he used for prying corals from the reef. He is seen above appearing like Neptune from the depths, having climbed to the top of a coral shoal after a 25-foot dive down its precipitous side

(*Right*) Diving near a coral shoal to which the boats have been anchored. Doctor Miner is standing on the brass-rope ladder waiting for the diving helmet to be placed over his shoulders. Two sailors stand ready at the air pumps. Wyllys Betts (with goggles) swims near by. The boat contains waterglasses, undersea tripods, and other diving equipment

Photo by Toshio Asaeda

Photo by Roy Waldo Miner

(*Left*) Doctor Miner goes down. The diving helmet has been placed over his head, the pump started, and the air, entering the helmet through the hose, keeps the level of the water below the diver's chin. Though the helmet weighs 65 pounds in the open air, it immediately loses weight when submerged. The ladder rungs are set one foot apart. The diver counts them as he descends so as to know the depth at which he steps off the ladder

(*Below*) Doctor Miner at the bottom of the sea. The submarine tripod and the rope ladder are visible beyond him. He is examining a cluster of precious pearl shell

Photo by Chris Olsen

(*Right*) Tau has just descended with the submarine camera. After placing it on the tripod, he swims to his favorite pinnacle to watch the photographic operations

Photo by Toshio Asaeda

(*Above*) Two divers are down, as shown by the double line of hose, the patches of bubbles, and the shadowy diving helmets visible through the disturbed but clear water

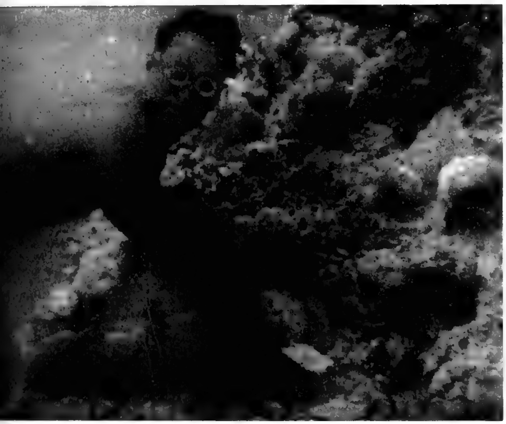
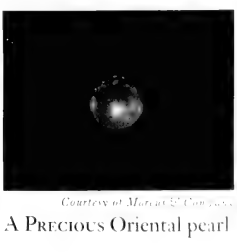


Photo by Roy Waldo Miner

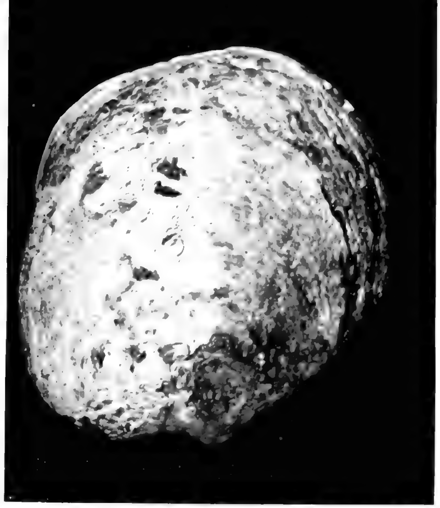
Tau, the Tongarevan diver, has discovered a large cluster of pearl shell and calls the submarine photographer's attention to his find, as he severs the tough byssus threads by which they are attached to the sea bottom. The amphibious Tau stays at the bottom three or four minutes at a time. He rises to the surface at intervals to renew his air supply, returning immediately to his search for the pearl shells which grow abundantly in the lagoon

Photo by Roy Waldo Miner



Courtesy of Marcus & Company

A Precious Oriental pearl



AMNH

(*Above*) Typical Pacific pearl shell. The outside is rough and shows encrustations and growth lines. The interior (*below*) is lined with iridescent nacre or mother-of-pearl

(*Below*) Chris Olsen painting undersea. An oiled canvas stretched over plate glass is framed in a metal easel. Oil colors are pressed on with a palette knife

I took a step forward, half floating. A push of my foot sent me in a gentle, slow-motion stride over a pinnacle as high as my waist, and I settled down on the other side, my toes balancing on a great purple dome as lightly as thistledown.

UNDERSEA PHOTOGRAPHY

The silvery water surface above my head broke, and the legs and square top of my tripod appeared, pushing through with a cloud of bubbles as it hung grotesquely from a hook at the end of a cord. It was lowered with a series of irregular jerks to the sea bottom a few feet away. I made my way over to it deliberately with half-floating steps, allowing the pressing watery medium to support me as I did so, instead of wasting strength in trying to push it aside. When I reached for the tripod, my hand closed on nothing, for the magnifying quality of the water decieved my eyes in estimating distance. I groped toward it, in full vision, and watched my hand finally close about it like the hand of another person. Slowly I placed the tripod in position; and then I saw, hanging near by, one of the loaded camera boxes with motion-picture camera enclosed. I placed it on the tripod, took note of the distance for which it had been focused chalked upon its side, and signaled with my arm toward the lower end of a waterglass through which John was gazing weirdly down at me from above.

The surface water broke again, and a coil of line, weighted with lead sinkers, floated down to me. I fastened one end of this to the coral growth toward which the camera was pointing and measured the distance to my lens, counting the sinkers which had been attached at measured intervals for that purpose. I adjusted the tripod and camera, pressed the lever that connects with the shutter within, and ran off the film for a motion picture of the submarine vista with the strange and beautiful fishes that came flitting, like actors, across the coral stage. I repeated this in various directions until the film was completely exposed. I looked up to signal again and saw the legs of Tau, the diver, hanging near the boat. I raised my hand, and immediately he let go and sank down near me with another loaded camera box. He set it on my tripod, in place of the first, which I was now holding in my hand. Then he relieved me of my burden, and, with a push of his foot against the sea floor, swam vigorously to the surface, heavy box and all, to deliver it to the waiting hands of John. In a few minutes, Tau was down again and swam over to a neighboring pinnacle to which he clung, so as to watch me at his leisure. He rose to the surface occasionally when he needed air, but he always returned to the same spot to wait until my camera ran down, when he swam over to get it and take it again to the surface. He seemed like a veritable amphibian!

Now, down the ladder, came another pair of legs. It was Olsen, equipped with the other helmet. In his hand he had a nonrustable metal palette, with oil colors arranged around its margin in the conventional manner. When he reached the sea bottom, he waited until an easel of the same metal was lowered, framing a sheet of plate glass with oiled canvas stretched over it. He then carried this outfit a short distance away, set up his easel on a rock, and, standing before it, looking like a hobgoblin in his diving helmet, proceeded to lay oil colors on the oiled canvas, pressing them down with his palette knife, thus painting undersea the color and arrangement of the coral formations!

I turned my camera toward him and made a motion-picture record of this unusual performance.

OCTOPUS

On the sea floor, a short distance away, I now espied a fine cluster of living pearl oysters. I went over and examined them carefully. Returning to the camera, I made a careful photograph of them and of several other clusters which I discovered nearby. I signaled again, and Tau came swimming down. I pointed out the pearl oysters, and he swam over, separated them from the coral rock to which they were fastened by means of their tough byssus, and bore them to the surface in his arms. Meanwhile, all this was recorded by the camera. Olsen had now gone above, and Betts took his place. He came over and touched my arm to draw my attention to the side of the cliff, where an irregular cavern opened above a threshold of coral. A tapering serpent-like tenacle was sliding out over the rounded surface, followed by another and another, all armed with disk-shaped suckers! Immediately behind them a bulb-shaped head erected itself above a pair of baleful eyes, regarding me with basilisk-like stare. I turned to my camera, but the film had run out. I signaled for another, and it was quickly lowered to me. I made the exchange as rapidly as possible, meanwhile keeping an eye on the octopus. While I was thus engaged, the creature slid forward over the coral head, bringing all eight of its tentacles into view. Suddenly it launched forward into the water, bulb-shaped head foremost and tentacles streamlining out behind, and swam over to another ledge a little farther away. Meanwhile, I was struggling to adjust the new camera, but when I had it in position, to my disgust, the creature slipped around the shoulder of the cliff and vanished. Another opportunity lost! However, we later captured several others and were able to study them at close range in the aquarium on the deck of the *Zaca*.

Now for the "bang-bang"!

Many of the gorgeous butterfly fishes, goatfishes, filefishes, and scarlet-spotted tangs eluded all the usual methods of capture, so I had to fall back on this unusual apparatus. It consisted merely of a bamboo pole about ten feet long, carefully weighted and balanced with sheeet-lead, and having at its end a couple of dynamite caps. Attached to these, a long insulated and waterproofed electric cord was looped along the pole, passing through my hands, and extending 30 feet upward to the boat, where John sat with a switch box between his knees. I would walk along the sea bottom in my helmet, holding the pole out in front of me, stalking the fish I wanted. When I managed to get the caps about a foot above the head of a gaily colored

butterflyfish, I would jerk the cord, as a signal to John, who would then close the switch. There would be an explosion, and the fish would flop over, stunned but not killed. Meanwhile, Tau would be swimming at the surface, with a hand net, watching me through the goggles that he always wore undersea. As soon as he heard the explosion, he would swim down, capture the fish in his net, swim to the surface, and turn it over to Toshio, who was waiting in the launch. The Japanese artist would quickly put the fish into a pail of sea water, where it would soon recover. Meanwhile, he would make an accurate record of its color pattern, while still in its fresh condition, before captivity had caused it to fade, as is often the case. This process was repeated again and again. When we returned to the *Zaca*, Toshio would make finished paintings, utilizing his sketches as data, while Olsen and Betts would make plaster molds of the fish. Later, when we reached the Museum, we made wax casts of the fish from the molds, which could then be colored from Toshio's paintings to make life-like replicas of the fish.

THAT ALL CAN SEE THE DIVER'S WORLD

For nine successive days we made trips of this kind to all parts of the lagoon, according to the plan we had evolved when we arrived. We dove morning and afternoon, staying down in the warm transparent waters as long as we wished. I made more than 70 dives during that period, and Olsen and Betts kept the other helmet just as busy. We took thousands of feet of undersea film, made hundreds of sketches of the living fishes and corals in color, secured scores of pearl shells, ten tons of beautiful corals, and specimens of many other invertebrates, as well as notes of many original observations. While we were working, we saw plenty of sharks, morays, octopuses, and poisonous starfishes, and had some interesting experiences with them, but, fortunately, nothing of a serious nature occurred.

Our largest and finest coral is a beautiful spiral growth weighing 900 pounds and measuring five feet in diameter. This is now a conspicuous feature in the Pearl Divers Group in the Hall of Ocean Life of our Museum. We also photographed the native divers while they were collecting pearl shell and made careful photographic studies of them ashore, from which life-size models were afterward constructed for the group.

A SUBMARINE FAIRYLAND

The Pearl Divers Group, which has been built as the result of this expedition, is now on public exhibition. It has involved much precise and unusual technique to produce it on the part of the artists and modelers of our Department of Living Invertebrates. It represents two Tongarevan pearl divers plunging down into a coral gorge, faithfully reproduced from one of the magnificent formations that we actually visited on the sea floor of Tongareva. In the midst of this submarine fairyland, they are engaged in plucking precious pearl shell clusters from the ocean bed, daring the menacing octopus sliding out from the entrance of a mysterious sea cave. The divers swim and grope past beautiful and grotesque coral growths to find their prizes among sea gardens of stone flowers, glowing in all the soft colors of the spectrum, while fishes of every gaudy hue dart past them. Beneath the great spiral acropore coral in the center lurks a scarlet, sixteen-pointed sea star with hundreds of poisonous spines menacing from its upper surface.

Among the corals on the bank toward the left, may be seen a bed of furbelowed *Tridacna* clams with sinuous openings, festooned with gaily colored mantle-edges. These are the man-trap clams, to be avoided by the hands or feet of the swimmers, lest the unwary diver be caught and held between the vise-like valves.

Over on the right, the visitor is given an opportunity to peer through a special opening into the Cave of the Octopuses, to spy upon the grisly inhabitants at home, while a vista into the distant waterworld is glimpsed through a submarine tunnel.

The group, as a whole, reproduces a characteristic association of sea creatures typical of the coral reefs of the tropical Pacific and illustrates one of the more primitive methods of fishing for precious pearls.

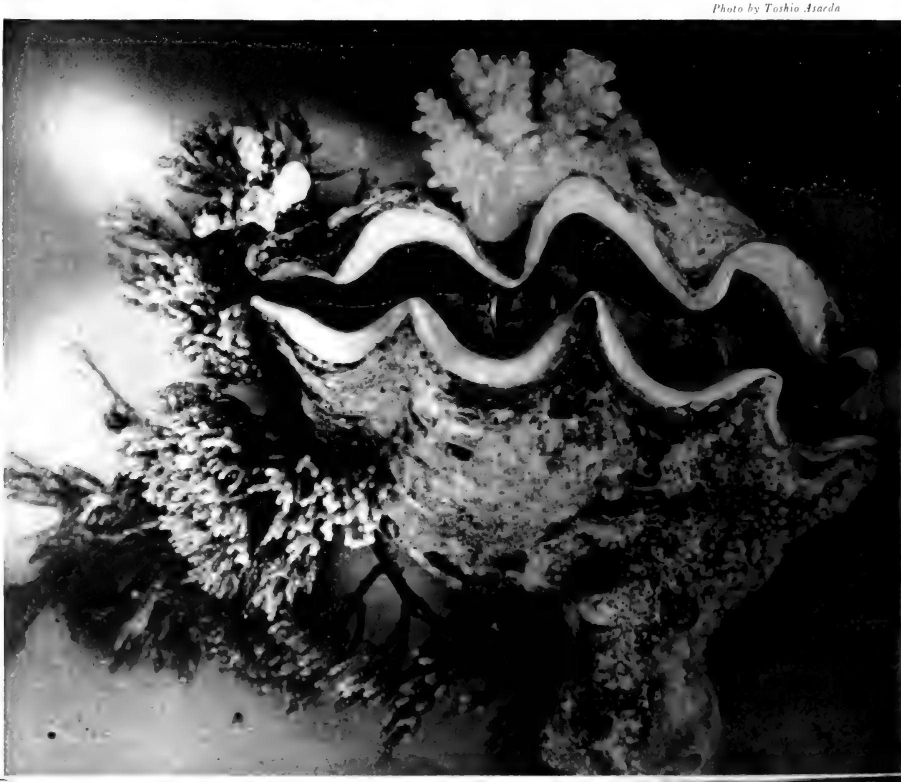
(*Left*) UPPER SURFACE of a shoal of living coral photographed through two feet of water. The anchor rope of the work boat is visible across the shoal at the left of the picture

Photos by Wyllys R. Betts

(*Left*) EDGE of above shoal with closer view of the coral growths. The water is so transparent that clusters are visible even at a considerable depth

(*Below*) A LIVING *Tridacna*, the furbelowed or man-trap clam. Between the slightly open valves of the shell may be seen the thin membrane of the mantle cavity pierced by two mantle openings. The oval margin of the left-hand aperture is visible, showing the mottled lining of the mantle cavity within. The thick edges of the mantle, adorned with multitudes of thin, brilliantly blue stripes, are expanding over the scalloped edges of the shell

Photo by Toshio Asaeda



(*Above*) Part of the coral collection of the expedition, assembled on the dock at Tongareva after having the outer animal tissue removed

(*Below*) The largest coral collected, weighing 900 pounds. Secured with difficulty by Frank Tiaga and two Tongarevans, it is shown here being hauled aboard the *Zaca* after being brought from across the lagoon. The entire coral mass is five feet in diameter and now forms an important feature of the Pearl Divers Group in the Museum

(*Above*) THE GREAT acropore coral specimen aboard the *Zaca*. Its unusually symmetrical form and the spiral character of its growth are well displayed in this picture. This coral, together with the rest of the collection, was brought to Pago Pago, Samoa, on the *Zaca*. Two Samoan natives are seen in the distance

(*Left*) THE LARGE CORAL being permanently packed for shipment to the Museum. Its bottom was carefully secured and the specimen braced against the sides of the box, while they were being built around it

(*Below*) FRESHLY collected corals were brought aboard the *Zaca* at Tongareva, placed in tubs of sea water and thoroughly washed by hosing to remove the animal tissue covering the outer surface. This is known as "bleaching"

(*Right*) The complete collection on dock at Pago Pago, still roughly packed as it left the *Zaca*. The skilled sailors at the Naval Station carefully crated the entire ten tons of material for shipment to the United States. The collection included corals and hundreds of pearl and *Tridacna* shells. In the foreground may be seen plaster molds made directly from the fishes collected for the group

(*Left*) A detail of the completed Pearl Divers Group. A native diver, equipped with goggles and simply clothed in a *pareu* twisted about his loins, is detaching clusters of pearl shell from the sea floor at the bottom of a beautiful gorge in the lagoon of Tongareva. Near by, an octopus glides out from a crevice overarched by precipitous walls of fantastically eroded limestone covered with delicately branching growths of coral, alternating with massive domes and grotesquely weird foliations. Brilliantly colored fishes flit in and out of the sea caves

The group was constructed, under Doctor Miner's direction, by Chris E. Olsen and Bruce K. Brunner, assisted by Dr. George H. Childs and Worthington H. Southwick. The life-size figures of the pearl divers were modeled by John W. Hope

(*Left*) A NATIVE gracefully plunges into the depths of the coral fairyland in search of pearl shell. The spiral turret of the great acropore coral, the prize of the collection, is shown in place in the lower right-hand corner of this view of the finished group

(*Above* and *below*) CAREFUL photographic studies were made of the Tongarevan natives from which the Museum sculptor constructed the life-size figures of the divers

Photos by Toshio Asaeda

AMNH photos by Coles

(*Left*) Through an opening at right side of the Group is depicted a vista through the cavern of the octopuses. A grisly individual is gliding menacingly down from the rocks above

The expedition was made possible by Templeton Crocker and his yacht, ZACA. The group itself is the gift of the late Edith Haggin de Long.

The expedition personnel consisted of Doctor Miner, Wyllys Rosseter Betts, Jr., and Chris E. Olsen.

THE PEARL DIVERS GROUP

This group represents a scene on the sea floor of the enclosed lagoon of the coral atoll of Tongareva, a little ring-shaped island eleven miles in diameter situated in the South Pacific Ocean about 2000 miles due south of Honolulu. Through the large central opening, two Tongarevan pearl divers are seen plunging down into a coral gorge in the heart of one of the magnificent submarine formations of this beautiful island. They are engaged in gathering precious pearl clusters from the ocean bed in spite of the gruesome octopus at the entrance of a nearby cave, the poisonous sixteen-pointed sea star armed with hundreds of sharp red spines, and the shark lurking in the watery distance.

Through the window at the left, a bed of furbelowed *Tridacna* clams is seen half buried in the rocky slope which rises to the cliff-like coral wall of the gorge, their sinuous openings gaily festooned with brightly colored mantle edges.

At the right of the group, the visitor may look into the cave of the octopuses, one of which slides threateningly down from a rocky shelf above. Another lurks in a shadowy crevice, while a third octopus, swimming out through an arched tunnel into the distant watery vista, trails its tentacular arms behind.

This group emphasizes the delicate beauty of the fairy-like corals of the South Seas, among which the Polynesian divers spy out the precious pearl shell, as contrasted with the strange and weird giant branching species of the great Bahaman Coral Reef Group, also at this end of the Hall of Ocean Life.

The Pearl Divers group is the gift of the late Edith Haggin De Long, whose generosity has made possible not only the elaborate modeling and assembling of the group itself, but also the mural on the gallery floor immediately above. This fine painting by Francis L. Jaques depicts the pearl divers plunging from their outrigger canoes to secure the precious shell as shown in the main group below.

The expeditionary work for this group was undertaken during the Fall of 1936 through the generosity and cooperation of Templeton Crocker of San Francisco who accompanied the expedition and placed at the Museum's disposal the facilities of his graceful schooner yacht, the ZACA. Contributions for this trip were also made by Junius S. Morgan, George T. Bowdoin, Clarence L. Hay, and Wyllys Rosseter Betts, Jr. The Museum personnel consisted of Curator Roy Waldo Miner, leader, Wyllys Rosseter Betts, Jr. as field associate, and Chris E. Olsen, departmental artist and modeler. An account of this expedition is given in the accompanying text.

The group itself was conceived, designed, and directed by Dr. Miner. The submarine background is by Chris E. Olsen, who was also the chief modeler of the exhibit. In this, he was ably assisted by Bruce K. Brunner. The excellent work of these two artists characterizes the major part of the display. The fishes represented were carefully cast and beautifully colored by Dr. George H. Childs, the scientific artist of the department, from molds made in the field by members of the expedition. The original field sketches for these fishes were painted by Toshio Asaeda, the expeditionary artist. Dr. Childs was also responsible for the accurate models of the octopuses. Ten tons of actual coral specimens are featured in the exhibit. The repair, preparation, and basic coloring of this remarkable series is largely the work of Worthington H. Southwick. The two life-size figures of the Tongarevan pearl divers were sculptured by John W. Hope.

THE AMERICAN MUSEUM OF NATURAL HISTORY
NEW YORK 24, N. Y.

CANYONS UNDER THE SEA

By HAROLD E. VOKES

THE AMERICAN MUSEUM *of* NATURAL HISTORY

CANYONS UNDER THE SEA

By

HAROLD E. VOKES

GUIDE LEAFLET SERIES
of
THE AMERICAN MUSEUM OF NATURAL HISTORY
No. 105

EACH year many New Yorkers, as well as multitudes of people from other parts of this country, journey long distances at considerable expense to view the wonders of the Grand Canyon of the Colorado River, never knowing that within 130 miles of Manhattan there is a canyon about 50 miles long that is comparable to the Grand Canyon in depth, and probably more spectacular in appearance in that it is less than half as wide at the rim. We cannot compare the two in scenic effect. We do not know whether the marvelous coloring of the rocks of the Grand Canyon region is duplicated here or not, for no one has ever seen the canyon! It is a submarine canyon whose rim is 500 feet below the surface of the Atlantic, and whose mouth lies at least 8400 feet deep.

Although the Hudson Submarine Canyon has never been seen, it has been quite accurately mapped during the past decade by the United States Coast and Geodetic Survey. The scale model of it, shown in the accompanying illustrations, has recently been completed in the American Museum of Natural History and is now on exhibition in the Hall of Ocean Life.

The existence of the canyon has been known for only a little more than half a century. It was in 1885 that Captain Lindenkohl of the United States Coast

CANYONS UNDER THE SEA

By H. E. VOKES

Assistant Curator of Invertebrate Paleontology, The American Museum of Natural History

Equal to the Grand Canyon in depth and having more precipitous sides, Hudson Canyon remains one of the great mysteries of the deep, for it represents a strange family of submarine features which no scientific facts can explain

and Geodetic Survey first announced that a *ravine* had been found at the edge of the continental shelf, near the end of the known submarine channel of the Hudson River. Only recently have deep-sea sounding methods demonstrated that such depressions are common features along the margin of the continental shelf and that they possess a depth and length such as to make the term "ravine" hardly appropriate.

On land, canyons are found cut into highland areas, either in mountains or plateaus. Their mouths are always at the lowest part of their course, generally where the highland slopes to join the lowland. They are almost invariably formed by moving water, either that of flowing streams, or by water frozen to form the ice of glaciers.

In the sea, the canyons are found in somewhat similar "terrain," being cut into the margins of the continents where these drop off into the true ocean basins. One is likely to consider that the edge of the continent is where the land dips beneath the sea. Scientists have long recognized, however, that the continents are great uplifted blocks, whose real margins lie some distance out from shore, at a point where the bottom drops off rather abruptly to the true ocean basin. In other words, the surface of the continent passes gradually beneath the surface of the sea

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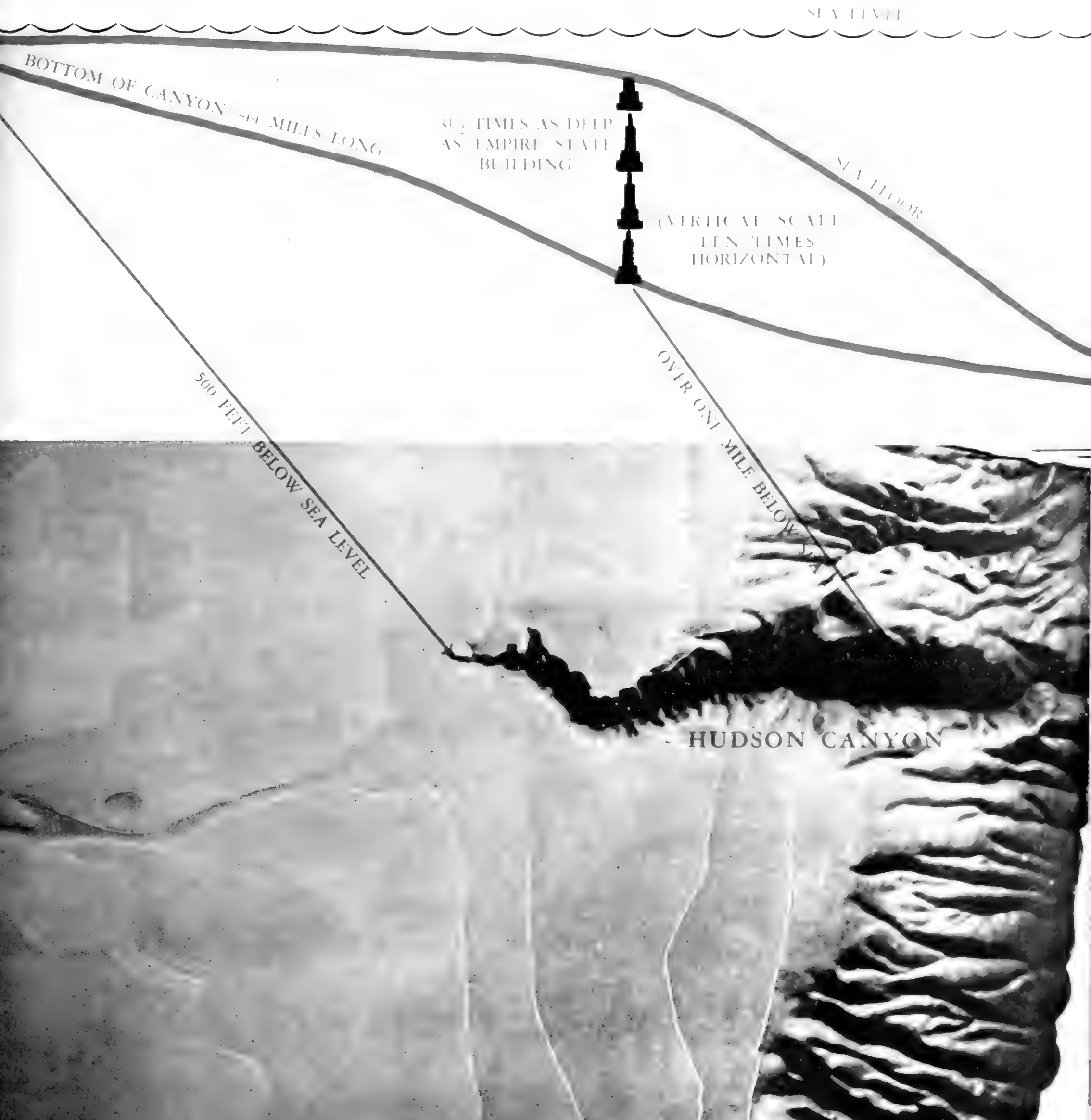


EL BY A. H. NILES UNDER WORKS PROGRESS ADMINISTRATION AND A.M.N.H.
PERVISION. DATA FROM GEOL. SOC. OF AM.—A.M.N.H. PHOTO BY COL

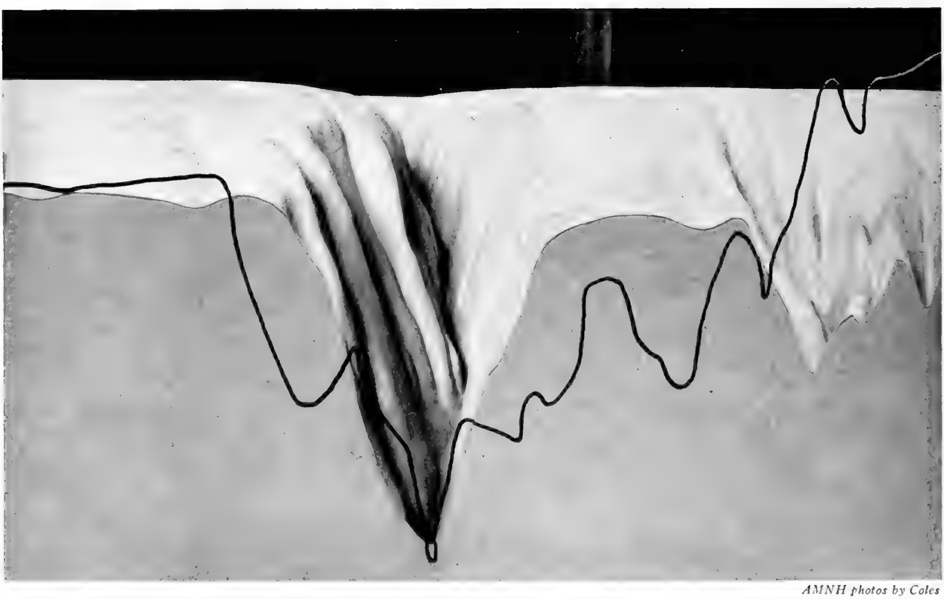
to a depth of approximately 600 feet in most places, at which point a sharper slope occurs. The submerged edges of the continents are referred to as the "continental shelves," and the submarine canyons are all cut into the shelves along their outer edges. The new model, which shows the shape of the margin of the continent in a very graphic manner, is eleven feet long and three and a half feet wide. It represents an area 164 miles long and 53 miles wide and was constructed in the Department of Paleontology with the assistance of the Works Progress Administration, the work being done under the supervision of the writer.

Submarine surveys made during the past few years have indicated the presence of a great many canyons similar to the one shown in the model. At the present time canyons are known to occur off all the edges of the continents save on the Arctic and Antarctic slopes. Their apparent absence is probably due to a lack of adequate surveys in those regions rather than to any considerations having to do with their method of formation.

Many of the canyons occur off the mouths of rivers, those off the Hudson River in North America and the Congo River in Africa being among the most spectacular. Others occur off the Ganges, Indus, Niger, and Columbia Rivers, as well as a multitude of smaller streams. This general alignment led to an early suggestion that the canyons had been cut by these rivers at some time when the continental margins were much higher in relation to the ocean level than they are today. But the recent investigations have shown that there are many gorges that cannot be related to any modern river. One of the more interesting canyons of this type begins almost at the head of the pier at Redondo Beach, California.

When canyons of this sort first became known it was suggested that they might possibly be very old features, perhaps dating even from 200 or 300 million years ago, in the Paleozoic era, and that all evidence of the eroding rivers had been destroyed in the subsequent eras. But within the past five years we have learned that the canyons are cut into rock containing more recent fossils (Cretaceous and Tertiary), and it is now realized that the canyons are young structures, geologically speaking, probably not older than the Pleistocene or glacial period of approximately a million years ago.

The suggestion was then offered that the amount of water frozen to form the glacial icecaps of that period might have lowered the sea sufficiently to permit the rivers to cut the gorges, and that the tilting of the continents under the weight of the glacial ice had so deflected the courses of the rivers across the continental shelf as to permit their cutting the canyons which today cannot be related to any present river course. For example, a large canyon, the Wil-



AMNH photos by Coles

HERE a line representing the cross section of Grand Canyon is placed against the cross section of the model of Hudson Canyon. Note that the canyon 130 miles offshore from New York City has almost the same depth but much steeper sides. (Both profiles show the vertical distances ten times the horizontal)

mington Canyon situated slightly northeast of Cape May, has been attributed to the eroding power of the Hudson River during one of the earlier glacial advances, while the present Hudson Canyon has been attributed to the erosion of this river during the last glacial advance. Numerous careful studies have indicated that the level of the ocean surface was indeed lowered by the water frozen into glacial ice, but all the evidence suggests that such a lowering cannot have been more than 300 feet. This is still some 200 or more feet above the level of the heads of most of the canyons, and no known river today has sufficient current to erode any such structures off its mouth at these depths.

It has been argued that we are misinterpreting the evidence and that the surface of the sea may have been lowered much farther than has been supposed. In answer to this, Professor Shepard of the University of Illinois has pointed out that the valleys extend to a depth of one or more miles and that the removal of enough water from the oceans to permit land at those depths to be cut by rivers would require the storage of about one-half of all the water in all the oceans and the piling up of an icecap at least fifteen miles thick on the continents. This seems impossible and is incompatible with all the evidence.

If the level of the sea was not lowered, perhaps the land itself rose, allowing the canyons to be cut, and then sank back beneath the sea. The amount of up and down movement necessitated by this suggestion is rather staggering to the imagination of the geologist. It would have had to occur along the margins of all the continents, and the amount of uplift would have to have been approximately equal everywhere, and the depression the same. One cannot conceive of such uniformity, geologically; furthermore, it is impossible to believe that such disturbances of the earth's crust could have occurred without leaving their mark on the adjoining lands, and there is no evidence suggesting such gigantic disturbances.

Despite the number of objections which have been raised against the possibility that the gorges were formed by river erosion, a number of students still believe that the true explanation of their origin will be found in this hypothesis. A multitude of other suggestions have been offered to explain the canyons. The recent great increase in our knowledge of their distribution and physical characteristics has shown that many of the earlier suggestions are wholly untenable. There are, however, still some five or six hypotheses which are receiving serious consideration by scientists engaged in the study of them. But there remain so many pertinent and significant objections against the acceptance of any of these that it seems probable that the correct explanation of how these gorges were formed (or are now being formed) has not yet been proposed.

Based on Plate I, Geol. Soc. America, Special Public, No. 7; Veach and Smith: Atlantic Submarine Valleys . . .

As elsewhere along continental shelves, a number of canyons are known to exist off our eastern coast. The canyons shown above are: (1) Hydrographic Canyon, (2) Veach Canyon, (3) Atlantis Canyon, (4) Block Canyon, (5) Hudson Canyon, (6) Wilmington Canyon, (7) Baltimore Canyon, (8) Washington Canyon, (9) Norfolk Canyon

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Roy W. Miner, *Chairman*

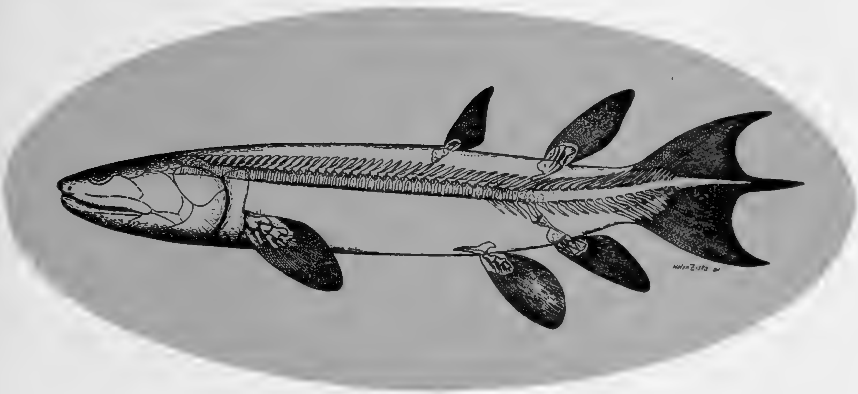
FAMILY TREE OF THE VERTEBRATES

Grandfather Fish and His Descendants

By

WILLIAM K. GREGORY

Curator, Departments of Fishes and Comparative Anatomy



GUIDE LEAFLET SERIES

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No. 106

FAMILY TREE OF THE VERTEBRATES

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GUIDE LEAFLET SERIES

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THE AMERICAN MUSEUM OF NATURAL HISTORY

No. 106

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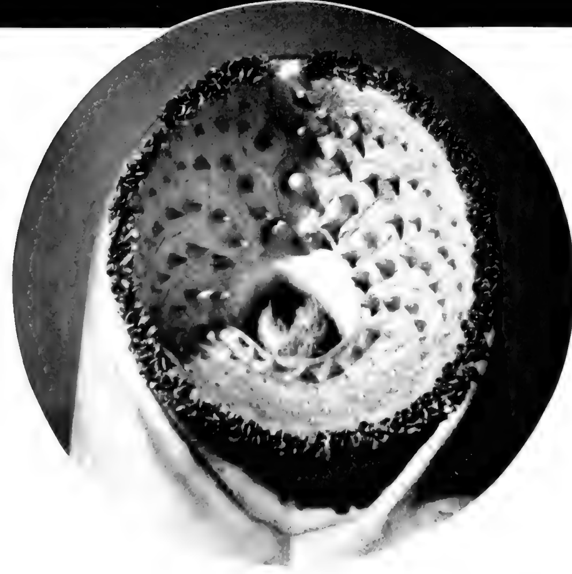
After Lankester

(Left) "GRANDFATHER" of 50,000 species of living animals and countless extinct ones: the 400 million-year-old "shell-skinned" fish, Cephalaspis. Its ground plan is seen to develop through successive evolutionary stages to provide the complex bodily features of all the modern fishes, amphibians, reptiles, birds, and mammals



(Above) ANOTHER LIVING FOSSIL descended from Grandfather Fish: the lamprey, front and side. Its efficient suction disk has permitted the lamprey to survive down to the present day in spite of its refusal to adopt a modern body design. Lampreys are sometimes popularly called eels, but in the tree of life they are farther from eels than eels are from man

Twenty-four centuries ago, the Greek philosopher Anaximander said that men were first produced in fishes and when able to help themselves were thrown up to live upon

GRANDF

By WILLIAM K. GREGORY

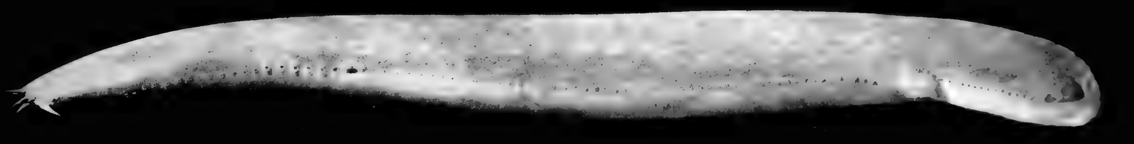
Curator, Departments of Fishes and Comparative Anatomy, The American Museum of Natural History

GRANDFATHER FISH lived so long ago that his personal history might seem to be of small importance to his remote descendants. Very few of them have ever heard of him anyway, and if they did they would promptly disown him. The very idea that man has been derived from a fish might seem to them even more fantastic than that man's ancestor was a monkey.

In this article we are not attempting to set forth the evidence for the reality of Grandfather Fish, for that evidence is scattered among thousands of facts and recorded in hundreds of books and papers. Neither are we assuming momentarily an improbability merely to lead to something better. We are only trying to sketch the introduction to a factual history covering several hundred million years in the transformation "from fish to man."

(Right) A VAMPIRE of the sea with an illustrious lineage. The modern hagfish is a "die-hard" that retained many of Grandfather Fish's basic features and survives today as a veritable living fossil. It lacks the true jaws of modern fishes and uses outmoded pouch-like gills. In place of a backbone, it has an elastic notochord. But it has developed a full kit of burglar tools for rasping a hole in the body of a fish and sucking out its blood. The portrait shown is from a model on display in the American Museum of Natural History. Directly below is a side view of the same creature

All photos by AMNH



the land. Modern science, piecing together the factual story, finds that this ancient theory was surprisingly farsighted. Here the celebrated author of *Our Face from Fish to Man* tells the first chapter in the evolution of backboned animals. Other chapters on the history of animal life in North America by various authors will appear in future issues

HER FISH and his descendants

Before we begin that history we must glance for a moment at its sources and documents. Broadly speaking these are: (1) paleontology, or the science of ancient life; (2) living animals, their zoology, embryology, and comparative anatomy, and (3) such newer sciences as experimental biology.

As to the documents of evolution, confusion has sometimes come from the very wealth of the evidence. There are estimated to be over 50,000 known species of backboned animals still existing, and if the known fossils are added, the number becomes even more bewildering. But there are easily available clues to this labyrinth.

Every beginning student in zoology is taught the rudiments of the classification of animals. He is expected to know that the smaller divisions, such as varieties, subspecies, and species, are combined in an ascending scale into larger groups called genera, and that these in turn are built up into progressively wider and more comprehensive assemblages called families, orders, classes, superclasses, and phyla. But what the student may not realize is that any individual cat, for example, besides being a sample of the species, also has the physical characteristics common to all members of the cat *family*, and, in decreasing numbers, those of the *order* of carnivores, of the *class* of mammals, and of the *phylum* of vertebrates. As a rule the popular mind as recorded in common speech thinks of one thing at a time and has a special name for it: cat, dog, bear, skunk, etc. And among specialists the idea has gained credence that the most important kind of knowledge is that which expresses the finer differences between different varieties of the same general kind. But when we study individual animals as representatives of larger groups, we find that the characteristics common to a broad division of animals, such as a class, are mostly older in the evolutionary story than those of the smaller division known as the family, and that the latter are in turn older than those of the genus, and so on down to individual peculiarities. This is like saying that the human race as a whole has had two arms and two

legs for a long time, but that the peculiar chin of the Jones family or the red hair of the Smiths is not an ancient or fundamental feature of the human race. The remains of ancient animals dug up by fossil-hunters show that the same principle holds true in the tremendously long story of animal evolution.

Thus the classification of living animals into broad and narrow divisions gives a fairly clear indication as to which characteristics are older and which are younger, and provides a helpful key to the history of animals, especially when used in connection with the fossil remains of the animals themselves.

The chart occupying the center spread of this issue of NATURAL HISTORY shows the important position that Grandfather Fish holds in the history of evolution. This chart will be found useful in connection with other articles that will appear in NATURAL HISTORY dealing with other chapters in the story of the origin of our animal life in North America. Here only 81 animals have been selected from the thousands that have made their appearance along the stream of time, but these few samples represent most of the main divisions of animals concerned.

The broader lines of descent and relationship are shown on the chart by the main branches and by the larger lettering. How have we discovered these lines? They are gradually coming to light as almost unexpected by-products of the exploration of hundreds of localities yielding fossils in many parts of the world. Nobody, for example, dug fossils anywhere with the purpose of proving that the most ancient and primitive fishes were the ones known as the ostracoderms, or "shell skins." Indeed, these shell-skinned forerunners of the true fishes were long thought to be "specialized and extinct side branches" of the supposedly unknown ancestral stock of the vertebrates. But, thanks chiefly to the later explorations of the Danish East Greenland Expedition and to the intensive work of Doctor Stensiö of Stockholm, it is coming to be realized that the ostracoderms as a whole have the basic requirements for this key position in evolution. This means that we may properly search among them for Grandfather Fish,—the type of fish that is responsible for all the hosts of backboned animals that today inhabit the land and waters. With regard to the many intervening types of vertebrates, whether or not we know their *exact* ancestors and descendants in each case, we are getting better and better evidence of what led up to them and where they belong in the general sequence of events.

Finally, we have certain animals on earth today that are conservative "die-hards,"—"living fossils" which have lagged behind their progressive relatives and retained for our inspection much of the internal ground plan of their remote ancestors. Among living creatures, the lampreys (often wrongly called eels) preserve the basic features of the ostracoderms. For example, they have no true jaws of the complex type presently to be described, and their gills are pouch-like. Also they have a large elastic rod along the back, known as the notochord, which all backboned animals possess before birth but discard for the more rigid and serviceable backbone. Therefore, though the lampreys are millions of years removed from Grandfather Fish, they are classed with him and the ostracoderms, under the superclass Agnatha (jawless).

Grandfather Fish seems to have fed on small living things, probably by sucking them into the mouth slit by a pumping action of the throat. But his descendants, the lampreys and hagfishes, attack other fishes, hanging on by a horny sucker that is armed with sharp thorns, and rasping the flesh of their victims with their thorn-studded tongue.

While the earlier ostracoderms fed on small creatures or floating organic particles, all their principal descendants later attained a predatory or robber stage. Some never got further, others pushed on to become quiet vegetarians. Jaws, it may be noted, were primarily organs for seizing and biting living prey, and all the backboned animals above the ostracoderms and lampreys are frequently grouped together into a superclass called "gnathostomes," or jaw-bearing vertebrates. In spite of this classification, at least some ostracoderms (for example, Pteraspis) had a jaw-like bone in the lower margin of the mouth and a firm palate against which it could work.

In these shell-skinned ostracoderms the head and forward part of the body were usually covered with a shelly case. How did this condition come about? The physiologist Homer Smith has put forward an ingenious and highly plausible theory, as follows. When the still more remote and as yet undiscovered vertebrates came up out of the sea into the rivers and lakes, their blood, or body fluid, which was nearly as salty as the ocean itself, would tend to absorb the fresh water through the then naked or porous skin. Since fresh water tends to pass through a permeable membrane at a greater pressure than that of the saline blood, the fresh water would continue to be absorbed until a state of dropsical swelling would result. The proper balance for the animal was restored when its kidney tubules began to secrete an excess of calcium salts. These, being carried by the blood stream and deposited in the skin, eventually formed a waterproof armor of surface plates. Hence the building up of bumps and spikes on the surface plates, formerly regarded as a fatal specialization, seems to have been merely a stage in the evolution

Continued on page 163

The Chart

GRANDFATHER FISH AND HIS DESCENDANTS

The following is a detailed explanation of the most important groups of animals shown on the chart on the next spread. This chart outlines the evolutionary road from fish to man, as developed by Dr. William K. Gregory.

Since the period covered is about 400 million years, only the most significant steps can obviously be shown. During this long period, whole groups of animals died out without leaving any descendants to carry on their line. Other large divisions, on the other hand, continued in greater or less abundance to give us the estimated 50,000 different species of backboned animals that we have on earth today.

The chart will be found useful also in connection with succeeding chapters on the history of animal life in North America that are to appear in NATURAL HISTORY Magazine.

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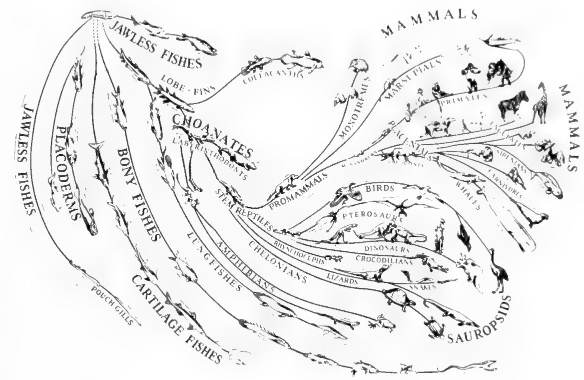

JAWLESS FISHES (Agnatha). These are the oldest and most primitive known chordates, or animals with a notochord or core of the backbone. The group includes the ostracoderms (shell skins) of the Silurian and Devonian ages and their pouch-gilled modern descendants, the lampreys and hagfishes. The casts of the internal structure of the head of ostracoderms reveal paired organs for smelling, seeing, and balancing. These collectively are included in the "basic patents" for the control system of all higher vertebrates, including man. The ostracoderms, although diversified in body, also show the beginnings of median and paired fins, and their motor units, as in higher vertebrates, are the red muscle fibers.

PLACODERMS. This large group was basally intermediate between the "jawless" and the "jawed" vertebrates. It showed an early stage in the formation of complex "gill-arch jaws" plus tooth-bearing jaw plates. The higher placoderms included the curious "joint-necks," an extinct group, mainly gigantic predators.

CARTILAGE FISHES. Sharks, rays, and their fossil relatives and ancestors are included in this group. Its members are generally primitive in their jaws, teeth, and internal organs, but the gristly state of their skeleton is now believed to be due to the retention in the adult of an embryonic condition. The sharks possess greatly developed smelling organs, while in the bony fishes *(see below)* the sense of vision is predominant.

BONY FISHES. These in the broader sense include the vast majority of still existing fishes. In the earlier forms, called ganoids, the massive scales had a thick bony base and were covered with a shiny layer of ganoin. In the modernized bony fishes, or teleosts, the scales have lost the bony plate and the ganoin, and have become thin and horny. The teleosts display the utmost diversity in body form, fins, jaws, teeth, food, and breeding habits. They are very far removed in structure and in time from the stock which gave rise to the land-living vertebrates.

CHOANATES. These include the air-breathing fishes with internal nostrils, including the lungfishes, the lobe-fins, and the ancestors of all the four-footed land-living animals, scientifically known as tetrapods. The chief divisions are:

Lungfishes. These form a side branch appearing in the Devonian and continuing up through all the ages into the existing Australian, African, and South American lungfishes. On the roof of the mouth they have a pair of dental grinding plates like two fans arranged back to back, which work against similar plates on the inner sides of the lower jaw. Their paired paddles are elongate, leaf-shaped to thread-like.

Lobe-fins (Crossopts, Rhipidists). These are the central stock of the air-breathing fishes. They have strong dagger-like cutting teeth fixed to the jaws with greatly infolded (labyrinthine) bases. The group is characterized by paired paddles which are strong and fan-like but have a tapering jointed axis.

Labyrinthodonts. These are the first of the four-footed land animals (tetrapods). Their teeth are infolded at the base as in the lobe-fins, and the skull also is similar, though it lacks the opercular bones covering the gill chamber. The paired appendages, however, have become typically five-rayed, essentially as in all higher vertebrates. The shoulder girdle is not tied to the skull. The pelvis is subdivided into three bones on each side.

Amphibians (modern). In this group are the salamanders, newts, sirens, frogs, toads, and the worm-like caecilians. Their young are hatched from eggs spawned in the water or developed in a watery medium enclosed in a leafy covering. The "tadpoles" usually have fish-like gill arches and external gills. During metamorphosis, legs sprout from within the body, and the adult animal may become either fully land-living or secondarily water-living.

SAUROPSIDS. This vast assemblage includes all the diverse reptilian hosts, together with the birds. The extinct stem reptiles (cotylosaurs) grade back almost

GRANDFATHER FISH and his descendants

By WILLIAM K. GREGORY
Curator, Departments of Fishes and Comparative Anatomy, The American Museum of Natural History

This chart shows 81 of the m
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† *Animals thus marked are extinct.*

Drawings by H. ZISKA *and* JOHN C. GERMANN

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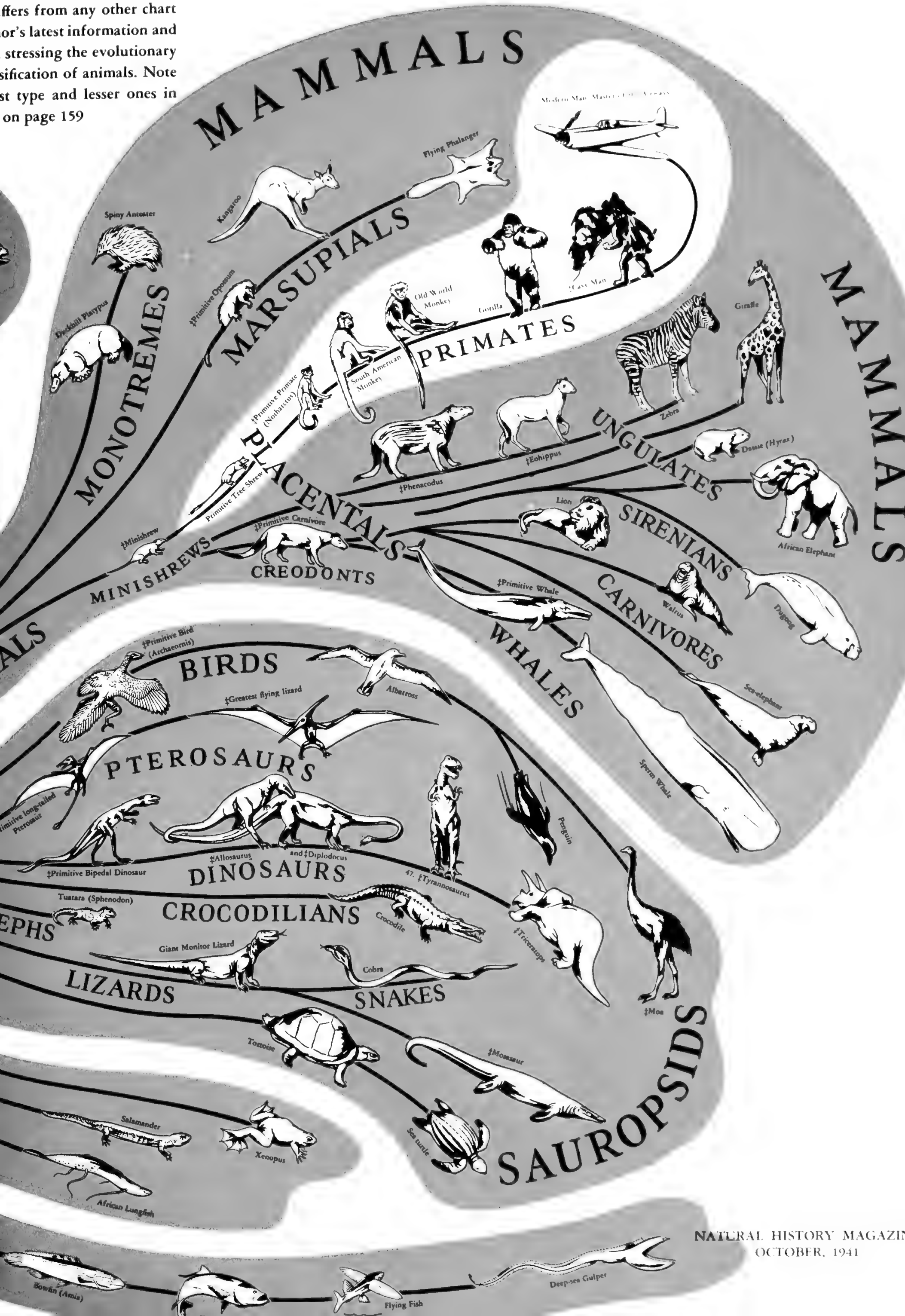
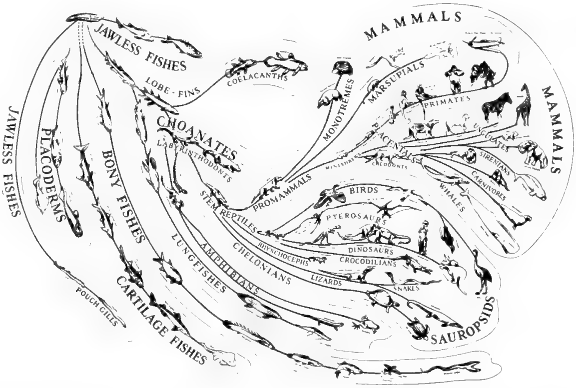


into the labyrinthodonts and forward toward the more typical saurians. In general the reptiles represent a further advance beyond the labyrinthodonts. They have succeeded in reducing or eliminating the fish-like or tadpole stage, and the eggs may be buried in the sand or hatched within the body of the parent. Devices for maintaining a more stable body temperature to resist severe changes are at best but poorly developed in the lower reptiles.

The main divisions of this group are as follows:

Chelonians. These are the turtles and their allies. They are the oldest branch of the stem reptiles. They have performed the amazing anatomical feat of developing a rigid dermal outer skeleton and at the same time drawing the top of their shoulder girdle well beneath the projecting rim of the first ribs. In the sea turtles the large forefeet have been changed into wing-like paddles.



Lizards. Though not far removed from the stem reptiles, the lizards have developed a skull in which the surface bones, especially those that originally covered the jaw muscles, have dwindled into narrow strips and bars.

Snakes. These are essentially lizards that have lost their limbs and acquired huge, loosely attached jaws for swallowing large prey. The extinct marine lizards (mosasaurs) were closely related to the existing monitors.

Rhynchocephs. These are represented today only by the tuatara of New Zealand. They were an early side branch equipped with somewhat rat-like front teeth, and are related to the lizards on one hand and to the stem of the dinosaurs on the other.

Thecodonts. These were slender fast-running, lizard-like reptiles of the Age of Reptiles, with many skeletal features that foreshadowed the ancestors of the crocodilians, dinosaurs, and other extinct groups.

Crocodilians. Now reduced to a few survivors (crocodiles, alligators, gavials), these were once a highly diversified group. They were an aquatic side branch from the ancient forebears of the dinosaurs. Many features of the skeleton are like those of dinosaurs, but others are highly peculiar. Their skull and jaws form an exceedingly efficient springtrap for capturing fish and even large mammals.

Pterosaurs, or flying reptiles. In these animals the enormously enlarged fourth finger of each hand served as a movable framework for a wing membrane. These reptiles, although excessively specialized, were a side branch of the thecodont group mentioned earlier.

Birds. These are truly "glorified reptiles." The strong, greatly improved four-chambered heart and the presence of feathers and air sacs enables a high body temperature to be developed and maintained within wide limits.

PROMAMMALS, or mammal-like reptiles. The earliest of this series were small, lizard-like offshoots of the stem reptiles; but as we follow the history of the group, many of them became swift-running creatures, and some gradually approached the earlier mammals in the details of their skeleton. For example, the teeth in *Cynognathus* and related forms became differentiated into incisors, canines, premolars, and molars—all adapted for a flesh-eating diet and thus foreshadowing the central group of mammals. At the rear end of the skull the joint with the first or atlas vertebra of the neck was formed by a double ball-and-socket, as in the mammals. A bony palate of mammalian type was being formed, and the limb bones were becoming fitted for swift running.

MAMMALS. In general the mammals are characterized not so much by the fact that they "bring forth their young alive" (because certain sharks, lizards, snakes, and ichthyosaurs also follow this method), but because the newborn are fed with milk from the mother's breast. Among the mammals are the following:

Monotremes. These interesting animals (including the duckbill platypus and the spiny anteater) differ from other mammals in that their eggs are not developed into young inside the body of the parent but are laid, like those of reptiles. Also the breasts are represented only by milk-secreting depressions on the ventral surface of the body. But the skin is well provided with hair, as in mammals. The popular statement that the duckbill is a link between birds and mammals is entirely in error.

Although the oldest known mammals date from the upper Triassic period (about 165 million years ago), fossil remains of this group are for the most part exceedingly rare during the greater part of the Age of Reptiles. The most conspicuous examples are the numerous and diverse fossil jaws of very small mammals, ranging from the size of those of a mouse to those of a kitten, which have been found in rocks of the Jurassic period, near Oxford, England and in Wyoming, United States.

Marsupials. Near the close of the Reign of the Dinosaurs, another glimpse of early mammalian history is afforded by discovery of a lower jaw and parts of a skull associated with the bones of a dinosaur. These represent a primitive opossum, the forerunner of the great marsupial division of the mammals, in which the young are born in a very immature condition and are subsequently nursed in the mother's pouch.

Placentals. All the higher mammals, including carnivores, herbivores, primates, and whales, belong to this division, in which the unborn young float in the interior of a membranous bag. A part of the bag, called the placenta, is in contact with the inner wall of the mother's womb. Although the blood of the mother does not pass directly through the placenta, this absorbent organ is able both to select from the mother's blood nutritive material for the growing fetus and to excrete waste products from the latter into the maternal blood stream. Partly by means of this improved method of producing high-grade young, the placentals have become the dominant group of mammals in the present epoch of earth history.

The oldest known placentals are represented by a few very small fossil skulls and jaws found in the Upper Cretaceous rocks of Mongolia. Among these are some whose teeth, jaws, and skull appear to embody the fundamental features for the rise of all the diversified insectivores, carnivores, and derived groups of the Age of Mammals.

of the outer or dermal skeleton. And, especially among the later or true fishes, there is much evidence that teeth arose from little swellings or spikes on the surface plates of the mouth and gill region.

To make effective use of its jaws and teeth, an animal must usually be able to pursue its prey. Hence all predators, at least of the vertebrate type, have a complicated system of locomotor organs, the power of which is furnished by the red muscle fibers. The beginning of contractile tissue is suggested in the jellyfishes, in which the mouth and body wall already exhibit sensitivity and contractility, which are the basis of the nerve-muscle complex. But by the time of the ostracoderms the vertebrate stock had already reached the stage in which the muscle fibers were strung in parallel series along the sides of the body. These were separated by partitions into more or less **W**- or **V**-shaped strips, called myomeres. A long series of these muscular segments was arranged on each side of the elastic notochord. But the real secret of vertebrate locomotion is found in the crossing over of certain nerve fibers from one side of the spinal cord to the other. This arrangement starts a wave of contraction that runs down along one side of the body, while almost immediately afterward another wave is started on the opposite side. In this way, the primitive vertebrate, although by no means flag-like in shape, could "wave" its way along the bottom or weave through mud, and was eventually able to swim freely in pursuit or flight.

The ostracoderms when we first find them had already attained a considerable diversity of body form, as shown in the accompanying illustrations. Broadly speaking, the most primitive form was shaped somewhat like a flattened raindrop, while one or more specialized side branches were much flattened, like a skate, and another was narrow and tending to be ribbon-like *(Pterolepis)*. In the typical cephalaspid ostracoderms the head shield was almost semicircular in outline, domed toward the center. The eyes were on top and looked like a pair of spectacles. Presumably these creatures clung to the surface of rocks or moved slowly along on the bottom. In *Birkenia,* which appears to be related to the cephalaspid stock, the body was becoming quite fish-like with the small head streamlined into it.

The interior of the head of the more primitive ostracoderms was comparatively simple in plan. There were three right and left pairs of organs for smell, sight, and the balancing sense, arranged one behind another on each side of the middle. Between them was the brain, doubtless showing corresponding subdivisions, and behind them the medulla and spinal cord. Below the brain and main sense organs was the roof of the chamber into which the mouth and gills opened. Thus we see that this lowly ostracoderm had already achieved the general pattern and arrangement of a number of important organs that have been retained in all later backboned animals, including man.

When some of the ostracoderms died, the mud seeped into the blood vessels of the head shield and followed the tunnels in the skeletal tissue left by the cranial nerves. Thus when the entire mass was turned into rock, there was a permanent record of the blood vessels and nerve tunnels. Stensiö found that he could safely identify most of these vessels and nerves by careful comparisons with the similar parts in the existing lampreys.

As already mentioned, the initial step toward the development of complex jaws had been taken by Grandfather Fish, himself, who was already using some of the upper and lower plates around the mouth as tweezers or pincers. The next great advance is seen in the Devonian period (about 300 million years ago), when certain fishes (placoderms) began to enlarge the first of the internal skeletal hoops supporting their gills, as bases for the surface jaw plates.

From the placoderm stock the foregoing "basic patent" for complex jaws was transmitted with increasing modification in detail to the cartilage fishes, bony fishes, lungfishes, stem amphibians, and higher vertebrates. Unmistakable remnants of this arrangement may be seen in the jaws and throat of the embryos of existing fishes and higher vertebrates, including man.

The ostracoderms and placoderms also show very significant experiments in the formation of paired locomotor appendages. Even in some of the ostracoderms the sides of the body just behind the head shield were prolonged into rounded lobes or projections of the body wall, which presumably were more or less movable and served somewhat like the lateral stabilizers of an airplane. When, as noted above, the kidneys secreted an excess of mineral matter, it often accumulated on the surface in the form of spikes located along the back or on the sides of the body. Behind the spikes the skin was pulled up into a sort of fin or web. These backwardly curved spikes, like the other projections, served as stabilizers in keeping the fish on its course.

Later the **W**- or **V**-shaped muscle segments of the body began to attach themselves to the underside of the spikes and fin webs. From this it was but a short step to a stage in which the spikes could be raised or lowered, thus greatly improving the fish's ability to make quick turns. This took place in a group of placoderm fishes known as the acanthodians. The earliest ones retained widely based spikes, but

in later acanthodians the spikes became more and more slender, and the body elongated.

As we follow these early fishes along their predatory career, we see improvement in their machinery for attack. Thus we come to the Devonian "joint-necks," scientifically known as arthrodires. They receive their name from a useful horizontal peg-and-socket joint on either side between the head shield and the shoulder plates. When they were about to attack their prey, they raised the head and opened the mouth very wide. The front "teeth" on the larger arthrodires were somewhat like a parrot's beak. Behind the beak were shearing plates, like butcher's knives. Dr. Bashford Dean, the American Museum's first Curator of Ichthyology, with a humorous touch of understatement, said that the arthrodires were "doubtless unpleasant neighbors," especially to the fin-fold sharks (Cladoselache), which he himself made famous in zoology textbooks.

Thus most of Grandfather Fish's early relatives had the advantage of some sort of armor. As they became more formidably equipped with offensive weapons, however, and developed the ability to move rapidly, this armor was for the most part reduced or eliminated.

The story of the rise and diversification of the swarming lines of bony fishes (ganoids and teleosts) is demonstrated by thousands of fossil and recent forms. But here we must be content to say that the earliest bony fishes had bodies completely encased in an armor of thick scales with a bony under layer and a shiny surface of enamel (whence our name ganoid for these fishes, from the Greek *ganos,* shiny). The horny scales of modernized fishes are a later development.

Grandfather Fish might envy the jaws and feeding habits of the bony fishes that descended from him, because they became exceedingly diversified. From a primitive stage in which the upper jaw was fixed, one can trace the changes into highly protrusile sucking jaws, jaws armed with sharp-edged sabers, massive jaws with crushing teeth, tube-like jaws with little nippers at the tip, etc. It is hardly necessary to state that the modern fishes as a whole have become very far removed from the earlier lines that gave rise to those backboned animals which established themselves on land.

The modern sharks used to be regarded as paragons of primitiveness, but it is now coming to be realized that the gristly or cartilaginous base of their skeletons may instead be only a hold-over of a normally embryonic feature into the adult stages of life. In the cartilage fishes the pectoral fins range from slightly movable, wide-based keel fins acting as elevators and depressors in swimming, to flexible paddles with a narrow wrist-like base. As the muscles in the fin bud grew upward and subdivided into a fan-like cluster, so did the bony rods that supported them. Thus were produced large fan-like fins as in the skates, in which the individual rods could be moved in sequence like the keys of a piano.

As long as fish remained fish, their opportunities for invading the land were quite limited; and only a few forms of present-day fishes venture to risk the traditional fate of a "fish out of water." This undertaking was successfully achieved some 300 million years ago, however, in one of the most dramatic and far-reaching events in the whole history of life. The modern fishes which temporarily manage to live on land include the famous mudskipper, the tree-climb-

PROTECTION is afforded our surviving ganoid fishes, like those of the past, by their hard, enamel scales *(below).* Most modern fishes, on developing offensive weapons and rapid movement, adopted more delicate ones. This is the famous *Polypterus* of Africa

AMNH photo

ing fish *(Anabas),* and certain eels and eel-like fishes. Suffocation in air has been avoided either by developing an accessory enclosed gill chamber with a supply of oxygenated water, as in the labyrinth fishes, or by the further development of the lungs. These were the birthright alike of the lungfishes and the lobe-fins.

The early lungfishes were well equipped to burrow in mud and thus survive seasonal droughts, as their descendants still do in central Africa. But they never developed strong limb-like paddles, and in the later lungfishes the paddles have been reduced to long threads. In our search for the forerunner of the first land animals, the evidence leads up to the air-breathing lobe-fins; for they alone have the right combination of characteristics to give rise to the severally distinctive patterns of skull and skeleton found in the earliest amphibians.

We are speaking of very remote time, but even so, we of today have a link with that distant era before the backboned animals came out onto the land. A very specialized side branch from the lobe-fins were the coelacanths. The last of the coelacanths, it was formerly thought, perished with the dinosaurs at the close of the Cretaceous period. But in 1938 some fishermen who were trawling off East London, South Africa, hauled in a strange-looking five-foot fish. After careful study by Dr. J. L. B. Smith, this was proved to be the only known living descendant of the coelacanths.*

The oldest lobe-fins of the mid-Devonian had pectoral fins of the fringe-finned (crossopt) type with a jointed axis and delicate side rods; but the more advanced Upper Devonian fish known as *Eusthenopteron* had broad, spreading pectoral fins, supported by a strong skeleton *(see drawing).*

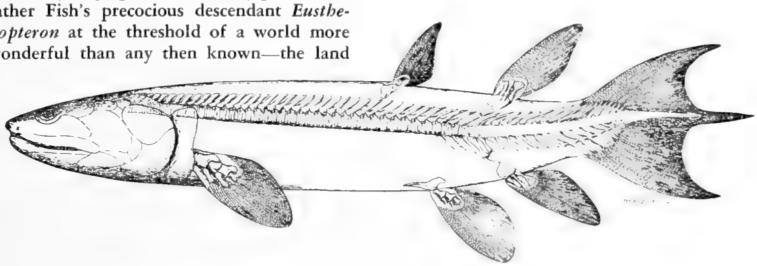
But exactly *how,* the reader may well ask, were the flexible paddles of the air-breathing lobe-fins able to bear the weight of the body on land, which eventually became perhaps their foremost duty? After several years' study of the fossil and anatomical evidence, my colleague, Henry C. Raven and I have ventured to put forward the following partly new theory. As the paddle became bent at the future elbow and wrist joints, its bones gave rise directly to the three arm bones—humerus, radius, and ulna—and to the central carpal bones of the hand. The bones corresponding to the ones farther out on our hands, on the contrary, seem to have come from new buds from the rear border of the original paddle bones, as indicated in the individual development of the living newts and salamanders. The horny rays of the fin must have diminished and finally disappeared, as they did in the lungfishes. Meanwhile the muscular lobe of the paddle grew outward and subdivided into the muscles of the hand. The rear paddle became modified in much the same way.

Thus *Eusthenopteron* stood almost at the threshold of a far greater and more diverse world than any that he or any other water creature had ever known. For when his descendants began to push their frog-like snouts up on to the river banks, our ancestors were taking the initial step toward the conquest of all the lands.

[*The epic story of the rise and evolution of our four-footed, land-living animals will be told in successive issues of* NATURAL HISTORY.—ED.]

*See Edwin H. Colbert, *"A Fossil Comes to Life,"* NATURAL HISTORY, *May, 1939, p. 280.*

PADDLE-LIKE FINS for "walking" on mud and the ability to gulp air occasionally put Grandfather Fish's precocious descendant *Eusthenopteron* at the threshold of a world more wonderful than any then known—the land



The First Land Animals

by
FRED S. ROMER

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THE FIRST LAND ANIMALS

By

ALFRED S. ROMER

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The first *Land* Anir

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Life had existed in the water for many millions of years before the first backboned animals ventured on land. What lured them to take this epoch-making step? Better food, more air, or greater safety might seem the answer. But the true reason is as astonishing as the fact that the "accident" of their adventure, populated the land with the 30,000 species of animals we know today.

FISHES are all very well in their way. As Doctor Gregory pointed out in last month's NATURAL HISTORY, we owe much to these lowly relatives of ours. In them were developed the basic bodily patterns that have made the backboned animals, or vertebrates, dominant among animal types; and in the course of the ages fishes have evolved into a vast array of types which successfully carry on almost every mode of life available for water dwellers.

But this is only the beginning of the story. Above the primitive fish lay other and greater opportunities for the vertebrates. Beyond the banks of streams and lakes where our early ancestors swam, lay the land. Plants had already emerged from the water in ancient days to clothe the earth, and primitive insects and a few other lowly animals had also come ashore. The vertebrates were not slow to follow. From the fish stage there developed four-legged land dwellers which, stage by stage, gradually conquered the surface of the earth.

The general nature of the steps, and the evolutionary position of the animal types which were affected were shown in the chart accompanying the preceding article in this series. From the lobe-finned fishes as ancestors there developed the amphibians, inconspicuous today but of vital importance in early times as the first vertebrates to set foot on land. From early amphibians, with the development of a shelled egg capable of being laid on land, came the first reptiles, which had definitely left all traces of a water-dwelling stage behind. Once these first reptiles were firmly established there began a great wave of evolutionary

TIMETABLE OF THE AGES

Eras	Periods	Estimated time since beginning of period (in millions of Years)	Important events
CENOZOIC (Age of Mammals)	Quaternary	1	Man
	Tertiary	60	Rise of mammals
MESOZOIC (Age of Reptiles)	Cretaceous	120	Extinction of great reptiles
	Jurassic	155	First birds
	Triassic	200	First mammals; Reptiles differentiate and dominate
PALEOZOIC (Age of Ancient Life)	Permian	225	REDBEDS
	Carboniferous	275	Amphibians abundant; first reptiles; First amphibians
	Devonian	340	Fishes abundant
	Silurian	375	
	Ordovician	[illegible]	First traces of vertebrates
	Cambrian	550 ↓	Lower animal types [illegible]

*Doctor Romer is one of the world's leading authorities on the first land animals. He has collected, studied, and described many of them, and has toured America and Europe in this line of scientific investigation. He has for many years explored the Texas Redbeds, where this chapter in the early life of our continent has its setting.—ED.

What happened when fishes first came out on land is vividly related in the Redbeds of Texas. These rocks contain the remains of many transitional animals—hang-overs from earlier days and forms hinting of things to come

ls

3 Conquest of the land was assured when archaic reptiles like *Seymouria (above)* stepped ahead of their amphibian ancestors. This animal lived in what is now Texas

2 The fins have become five-toed hands and feet. This primitive amphibian was probably well able to breathe air but had to return to water to lay its soft eggs. *Cricotus*, described in the article, closely resembled this animal, *Diplovertebron*

Left) The first use of fins as limbs is seen in this be-finned fish of about 300 million years ago. pairs of fins have developed into strong paddles. is *Eusthenopteron*, whose backward cousins were living when the Redbeds were formed

development which resulted in the appearance of the dinosaurs and other spectacular creatures of the Age of Reptiles. And eventually the characteristic birds and mammals of more modern times emerged.

The development of these more advanced types will form the theme of later articles in this series. Here we shall stick to fundamentals. We shall examine some of the early four-footed animals and try to find how and why and in what guise they accomplished that most dramatic step—emergence from the water to the conquest of the land.

For undertaking such an inquiry no better opportunity is afforded than in the early land fossils found in the 250-million-year-old Redbeds of western Texas.

Archer, Baylor, Wichita, Willbarger are the counties whence come the Redbeds fossils; Wichita Falls is the local metropolis; Seymour and Archer City smaller towns, which are often headquarters for Redbeds fossil-hunters. It is a land of rolling, brushy prairies, of great herds of cattle, occasional farms, with here and there a cluster of the oil derricks that have brought much prosperity to the region; a land with some unpleasant features—heat and thirst of a summer and an unpleasant abundance of rattlesnakes,—but on the whole a pleasant country to work in, full of the friendliness and hospitality of the Southwest. Here and there on the hillsides are the "breaks" for which the collector searches—places where storm waters have washed the earth bare and exposed beneath the soil the underlying clays, shales, and sandstones, often red in color, where fossils may be found.

Bones were first discovered here in pioneer days, two-thirds of a century ago, by old Jacob Boll, a Swiss botanist then teaching in Dallas. Their importance was realized by Professor Cope of Philadelphia, who immediately employed him to explore the field. Boll gave his life in this quest: he was taken ill and died soon after in his tent on the lonely prairie, with only a frightened boy to tend him in his agony. But others soon followed, and the work of many men over several decades gave us a considerable acquaintance with the life of Texas in early days.

Order of events

In the diagram on page 2 is a simplified geologic "timetable," listing successive eras and periods of the world's history. This shows the place of these Redbeds in the sequence of world events and their strategic importance in the study of the conquest of the land. These deposits were laid down at the close of the Carboniferous period (the period when the greatest coal deposits were formed) and the beginning of the succeeding Permian period which marks the end of the Paleozoic era, the Age of Ancient Life. This part of present-day Texas was then not a high prairie, but a low-lying delta country, apparently subject to occasional droughts, but covered with a rich vegetation. Across this lowland meandered slow streams, which arose in mountains situated in what is today east Texas and which emptied to the west in a great sea. In these streams and on their banks lived animals of many types, showing every stage in the emergence of vertebrates from water onto land.

Thus, in the Redbeds we find, existing at one time, representatives of a whole series of evolutionary stages,—just as in a single city we see buildings in use which represent different periods in the progress of architecture. There were typical lobe-finned fishes of the sort from which the land animals got their start; there were creatures that lived partly in water and partly on land; and there were even early reptiles, which had left the water entirely.

The fish ancestors of land animals were represented in Redbeds times by a form known as *Megalichthys,* "the big fish" (really not very big, only a foot or two in length). Like his other lobe-finned relatives, *Megalichthys* had what it takes to be the ancestor of a land form,—stout fins with muscles and bones, which needed only to develop further to become the typical leg of a land animal, and well-developed lungs for air breathing. By Redbeds times his cousins had already reached the land as amphibians, the class represented today by frogs and toads, newts and salamanders. But *Megalichthys* himself stayed on as a form old-fashioned even in those days, living for the most part a contented existence in his ancestral streams.

Next in evolutionary order among the animals of the Redbeds we see representatives of the earliest type of four-footed creatures. The advance had occurred a number of millions of years before, but an exceedingly archaic representative of the transitional type was present in the amphibian *Cricotus.* This fellow was an animal of fairly good size, ranging from a yard up to five feet or so in length. In general his appearance was somewhat like that of some of the modern salamanders, with a rather long and slender body, a long tail, and four short and feeble legs. But in internal architecture *Cricotus* was quite different from these living amphibians and in many ways exceedingly similar to his lobe-finned ancestors and relatives. Further, while *Cricotus* had developed land limbs, most of his existence appears still to have been spent in the water. He was potentially a land animal; but in reality this ancestral type of amphibian was little more than a four-legged fish.

How did land life begin? Why did amphibians such as *Cristotus* ever leave the water at all? Why did

Heat, thirst, and the danger of rattlesnakes must be reckoned with in the exploration of the famous Redbeds for the earliest land animals, but the region also offers the hospitality and charm that are characteristic of Texas. This land, now dry, was a low-lying delta country with luxuriant vegetation when the ancestors of all our modern land animals struggled to establish themselves.

their ancestors ever develop their fins into limbs capable of locomotion on land? Many answers to this problem have been suggested, but most of them are highly unsatisfactory.

"To escape from enemies," some have said. But the ancestral lobe-fins were among the largest and most aggressive fishes in their native puddles.

"To gain new food supplies," say others. But both early amphibians and their fish ancestors were not vegetarians but eaters of animal food, and there was little animal food on land at the time. There were some primitive insects, to be sure, but so slow and clumsy were the legs of the old amphibians that even an archaic cockroach would have had no difficulty in escaping.

"The lure of atmospheric oxygen" is another fine phrase, but it is pure poppycock as an explanation of the emergence of amphibians. For, as we have seen, the ancestral lobe-fin had competent lungs, and he did not need to leave the water to breathe. By simply lifting his nose to the surface of the pond, he would have the world's oxygen supply at his command gratis.

The real answer to the problem of the development of land limbs appears to be a simple one, although seemingly paradoxical: *legs capable of land locomotion were developed to enable their possessors to stay in the water!*

To visualize the situation, let us compare the type of life led by our friend *Cricotus* with that of his relative *Megalichthys*, who represented the fish stock from which he had come. Both appear to have led, in Redbeds times, much the same sort of life. The fish spent his life in the water, feeding upon minnow-like fishes found in abundance there. So, too, lived the amphibian *Cricotus*. He had legs but apparently used them only a little. Small fishes too were his diet, and like the fish he was essentially a water dweller. Under most circumstances the fish was as well off as the amphibian,—perhaps even a bit better adapted to an aquatic life, for the dangling legs

of the latter would be an impediment in swimming.

But it appears that hard times knocked at the door even in Paleozoic times, in the form of drought. The geological evidence strongly indicates that in the later periods of the Paleozoic era when all this happened, large regions of the earth were subject to great seasonal droughts. In regions plentifully watered at other times, the streams would be reduced to mere rivulets, deep pools would become foul and stagnant mudholes or even dry up altogether. What then would be the fate of lobe-finned fishes? For a time, and if the drought were not too severe, all might be well enough. They could come to the surface and take in air to make up for the oxygen absent in the water. Even if the pool in which they found themselves dried up completely, they might burrow into the mud and survive for a time.

But what if the drought were really severe, if the water did not return soon? Under these circumstances the immobilized lobe-fins would soon die.

Not so the amphibian. Under such circumstances his newly-developed legs showed their usefulness. *Cricotus* cared nothing for the land,—it was water he sought; and, unlike his finny cousins, he could seek it. Abandoning the dried-up pool and his dying lobe-finned relatives, he could crawl (although slowly and probably painfully) up or down the stream channels or overland; and then, reaching another pool in which water still remained, he could plunge in and resume his normal aquatic life.

Legs were not, we believe, "invented" as an adaptation for land life, but were a happy accident. Originally, it seems, they were merely an adaptation to help the fish-like animals that bore them to survive drought.

Cricotus, then, represents a first stage in amphibian evolution. By Redbeds days other members of the group had branched out greatly and passed far beyond his primitive level toward a true land life. For example, there was *Eryops,* who was a common Redbeds amphibian—a large form, six feet or more in length, powerfully built and having massive, if rather short, legs. *Eryops* may have been to some extent aquatic, but he probably spent much of his life ashore; and other amphibians of his time may have lived almost entirely on land.

Yet chained to the water

Almost entirely, but never completely. And here lies the reason for the eventual failure of the amphibians as land dwellers. The fault lies in their old-fashioned reproductive habits. A fish's eggs are, of course, laid in the water. So, too, are those of typical amphibians. Each year (as today among the frogs and newts) all amphibians must return to the water to lay and fertilize their eggs. The young, as is easy to see in the case of frog tadpoles, pass their early days as purely water animals, using gills for breathing and eating aquatic food. Then comes a violent change, a metamorphosis—the gills shrivel, lungs and legs develop, and many internal organs undergo marked reorganization: the tadpole changes into an adult which can exist on land. But even so, the adaptation to the land can never be complete, for the grown amphibian must be able to return annually to the water for breeding purposes.

This sort of thing is obviously highly inefficient. Suppose, for example, that the reader's car had to be so designed as to be used also as a motorboat. Such a machine can be made, but it would be expensive, inefficient for either line of work, and would probably have difficulty competing with either a proper boat or an ordinary automobile in its proper medium. So with the amphibians. Though able to survive drought conditions such as existed in the early days of the group, they are not remarkably good performers in the water. And the reptiles which arose soon after them are far better adapted for life on land. Faced with keen competition in both environments, the amphibians quite understandably became a "discouraged" group, greatly reduced in numbers, until today they constitute but an insignificant element in vertebrate life. The land they have almost entirely abandoned. At present a few toads range far afield, but most amphibians cling close to the banks, and some salamanders have slumped backward to a state in which they never emerge from the water.

Signs of such degeneracy were present even in Redbeds days, when amphibians were still fairly abundant. An example is *Diplocaulus,* seen at the water's edge in the illustration reproduced on page 9. This grotesque little creature had a broad, flat body and a flat and ponderous head. The limbs were so tiny that they could hardly have lifted the head above the water and surely could not have carried the animal about on land. Such a form was only fitted for a permanently aquatic life, and presumably it spent its days as a mud-grubber in pond bottoms.

The late Sherwood Anderson once entitled a short story "The Triumph of the Egg." This would be a fitting title for the story of the development of the reptiles, which had originated from a progressive amphibian stock shortly before the Redbeds times. In the Redbeds are very primitive stem reptiles (cotylosaurs), best typified by *Seymouria* (named for the county seat of Seymour near which its remains have been found). *Seymouria* was a rather small and stockily built little fellow (*see illustration*

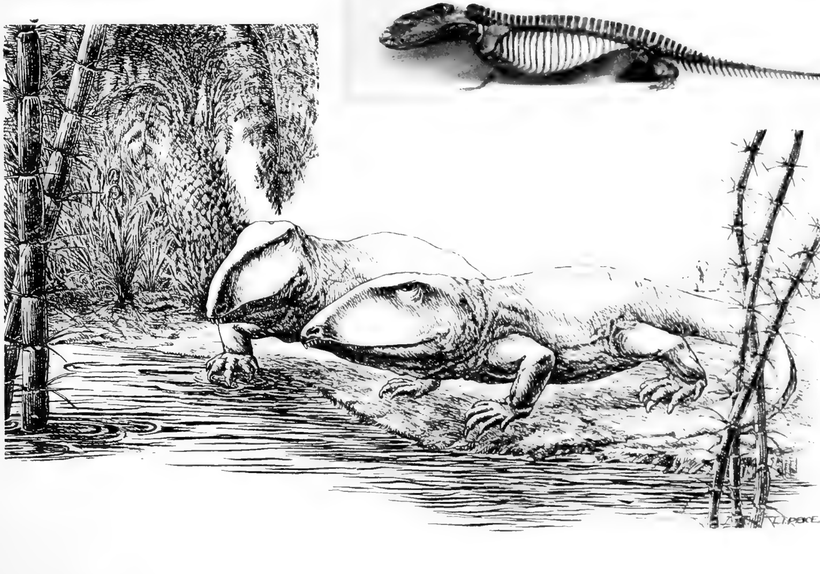
The Oldest Known Egg

THE KEY TO PERMANENT LIFE ON LAND: the earliest and only true egg from the Redbeds. The amphibians, though able to live on land, were obliged to return to water to lay their eggs, which had no shell to protect the delicate embryo within from drying up. This fossilized egg, discovered half a dozen years ago by a keen-eyed collector, Llewellyn Price, epitomizes one of the most dramatic chapters in the conquest of the land. Possessing a protective shell, it represents the basic patent which enabled animals to break the chain tying them to the water. The method of giving birth to living young was a still later development

(Below) THE SKELETON of *Ophiacodon*, reconstructed from the preserved bones. Here we have a primitive reptile which, however, had feet and skull that foreshadowed the emergence of mammals, the dominant class of animals inhabiting the earth today.

Geo. Nelson photo

A PRIMITIVE ANCESTOR ON THE MAMMALS. Certain of the reptiles, like *Ophiacodon* below, led the way in the direction of our vast assemblage of familiar four-footed animals of forest and field



From Prehistoric Life, *by P. E. Raymond, Harvard University Press*

on page 3). In his skeleton there are a few features which seem to show that structurally he was a reptile. But he was an exceedingly archaic one, and in many ways quite close to his amphibian ancestors.

The real reasons for the success of the reptiles over the amphibians lie not in the build of the adult body but in the mode of reproduction. The amphibian, as we have seen, is chained to the water. Since the young must develop there, and since the adult must periodically return there for the egg-laying season, the amphibian can never become a purely terrestrial animal. Not so the reptile. For in this group there has been evolved a new type of egg, which can be laid on land. This sort of egg is still laid by turtles and many a lizard and snake today. It is still present in even a few mammals (although most now bear their young alive); and it is found on our breakfast tables in the enlarged form adopted by the reptiles' avian descendants. The egg is protected externally by a shell, which is absent in amphibians. The shell, although firm, is porous; thus oxygen may enter and allow the growing embryo to "breathe." Within the shell a series of liquid-filled membranes gives additional protection to the young and prevents it from drying up. Still further, to supply the food which the encased youngster now cannot gather for itself, much of the egg is composed of a nourishing yolk. So equipped, the tiny germ inside the egg can skip the tadpole stage entirely and grow within its protecting shell and membranes to a point where, on hatching, it can at once take up an existence on land. By the shell-covered egg, the reptile has been emancipated from the water and can now become completely adapted to terrestrial life.

Oldest known egg

We have long felt confident that such a type of egg has been developed by the Redbeds animals that we characterize as reptiles. But fossil eggs are rare, although many a cobblestone in fossil deposits looks like such an object. The first—and only—true egg from these beds was discovered half a dozen years ago by a keen-eyed collector, Llewellyn Price, who immediately recognized its nature and importance. It is a small, oval, iron-stained mass, not at all exciting to look at. But its battered and cracked surface shows tiny patterns of the sort seen on many reptile eggs, and the microscopic structure shows definitely that this surface is an egg shell. This is the oldest known vertebrate egg—approximately twice as old as the famous and more abundant but relatively recent dinosaur eggs from Mongolia (*see photograph page* 7).

Once finally released from the water, there began the spectacular evolutionary development of the reptiles and their descendants. Even in Redbeds times we see the beginning of this reptilian radiation. And, most interestingly, the commonest reptiles of those early days (pelycosaurs) even showed the beginning of mammal-like tendencies.

The mammals, the warm-blooded, hair-bearing and intelligent animals that include man among their members, are such progressive forms that one might think that they developed late in the history of reptilian life. The reverse is actually true. As will be noted from our geological timetable, the first mammals appeared as early as did the dinosaurs. Advanced, very mammal-like reptiles were present at the beginning of Mesozoic days, and in Redbeds times their ancestors, as pelycosaurs, had already branched off from the main line of orthodox reptilian evolution.

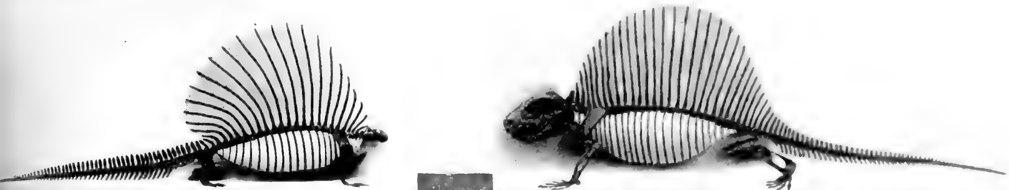
Typical members of these primitive mammal ancestors are such forms as *Ophiacodon* (*page* 7). This reptile was still very archaic, still very close to the primitive reptile type. He was, however, a bit slimmer, a bit longer-legged, and in details of feet and skull he shows the first faint traces of characteristics which later emerged full-fledged in the mammals.

Evolutionary experiments

No group of animals ever kept solely to an evolutionary main line; always there occur side branches, varied, short-lived "experiments." Among the pely-

SAILS? A short-lived evolutionary experiment among the early land animals was the development of peculiar extensions of the back among the reptiles known as pelycosaurs. This scene, reconstructed from scientific sources by the well-known artist Charles R. Knight, vividly shows the Texas landscape as it appeared a little over 200 million years ago. Two forms of "sail-carrying" reptiles are illustrated, *Edaphosaurus,* whose spines were shorter and had knobby side-branches, and *Dimetrodon,* whose "sail" was supported on long, smooth spines. Whether these animals went sailing around their prehistoric lakes with these appendages cannot be said. But, as any sailor knows, if they floated with the "sails" projecting above the water, they would most certainly have had to reckon with the wind

The reconstructed skeletons of these "sail-carrying" reptiles are shown below. At extreme left in the painting is a small reptile of the time, named *Casea*. At the water's edge at lower right, the grotesque little amphibian, *Diplocaulus*, raises its ponderous head above the water; its limbs were too weak to carry it about on land.



cosaurs such development resulted in the appearance of reptiles with peculiar "sails." The bones which cap the back in any ordinary animal grew upward as long spines between which, we believe, there stretched a continuous covering of skin. Two such types are shown in a mural by Charles R. Knight (*see illustration*). In one (*Dimetrodon*) the spines supporting the "sail" are long but smooth, slender rods; in a second (*Edaphosaurus*) the spines are shorter but with knobby side branches that have been compared with the yardarms of a ship. The purpose, if any, of this peculiar type development is quite unknown. The original describer of these forms suggested facetiously that these reptiles went sailing about the Redbeds lake with them. This idea is not better but also no worse than any other that has been advanced.

Redbeds animals were not as big as those of later days. Although some of them are rather peculiar in build, they lack for the most part the "glamour" of some of their more advanced and spectacular descendants in later geologic periods. My brethren in the bone-hunting game may have their dinosaurs or what not; the writer, at any rate, prefers these older fossils. The study of Redbeds animals is a difficult and tantalizing process. Collecting them is often a dreary task, fraught with heat, thirst, and discouragement. But these ancient fossils are important and their collection well worth the trouble. Land dwellers have progressed far beyond the condition of their crude and ungainly Redbeds ancestors. But the first steps in any process are the most important ones; and, both literally and figuratively, the first steps in land life are revealed to us through the animals of these ancient beds of the Southwest.

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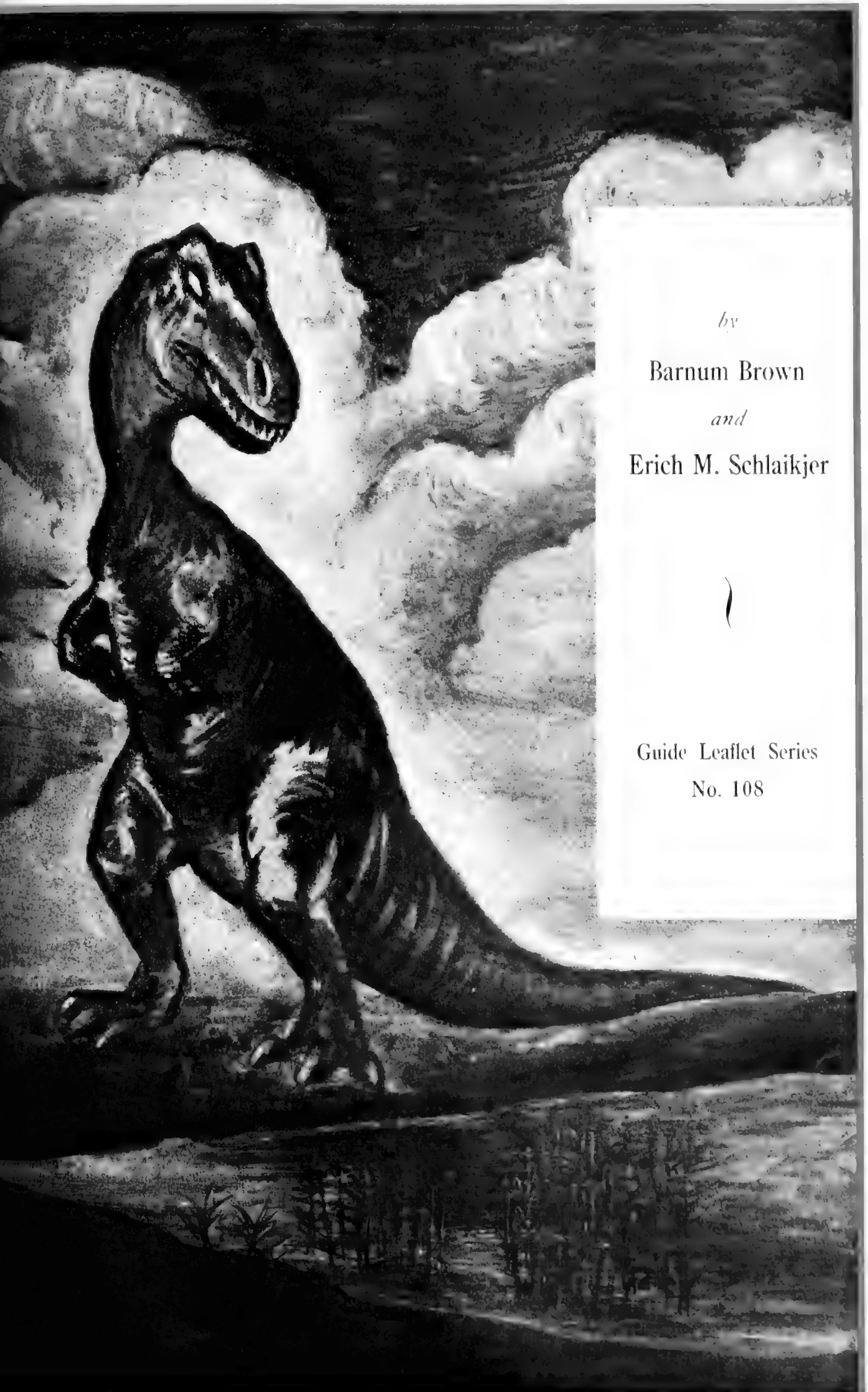
THE RISE AND FALL OF THE DINOSAURS



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THE RISE OF THE Dinosaurs

By ERICH M. SCHLAIKJER

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"Leaping Lena," humble forerunner of creatures that could nibble leaves "four stories" above the ground, gave little promise that her race would rule the earth for 140 million years

***At right,* THE 75-FOOT "THUNDER LIZARD," representing the Golden Age of Dinosaurs, looks back 50 million years at a pair of early dinosaurs only a yard long**

Drawing by ALASTAIR BROWN

BIG bones, little bones, all strung together and supported by wires, bolts, screws, and curling pipe—60 or 80 feet of it. Why, it's the biggest thing in the biggest hall in the Museum—yes, in any museum. It's a dinosaur, or "terrible lizard," as the word is usually translated from the Greek.

Even a hundred years ago these ungainly looking things were called dinosaurs. Not all of them, however, are so big or so terrible. This name, though of little scientific standing, is used for the greatest and most diverse group of animals on record. Some were small—no bigger than a jack rabbit and very meek in appearance; others, in fact most, were quite terrible looking. They came into existence 200 million years ago at the beginning of the Mesozoic era, or Age of Reptiles, spread over the whole earth, and then vanished after 140 million years of triumph.

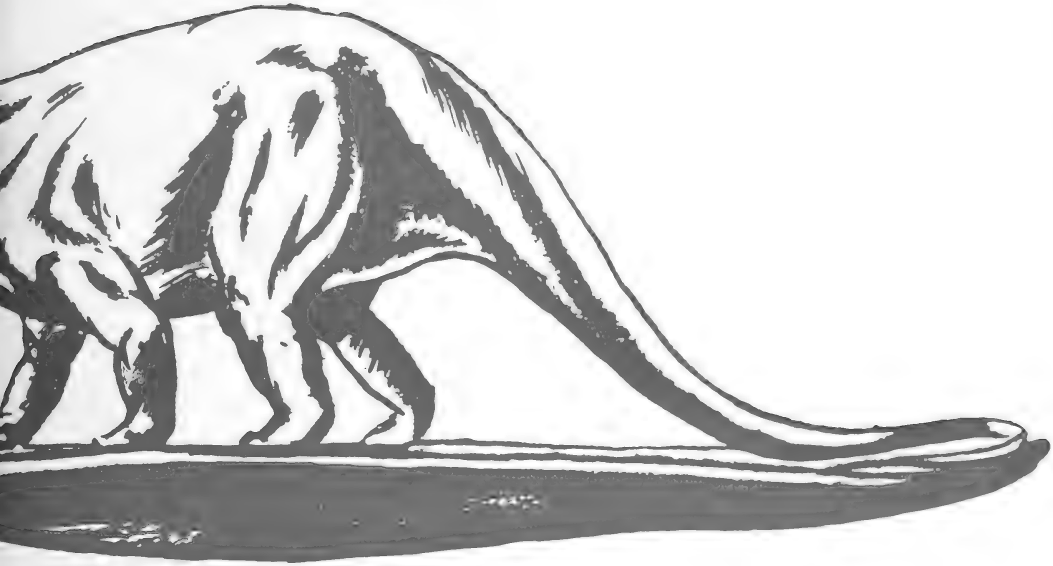
One hundred and forty million years is a long time for any group of animals to rule the world, but the dinosaurs were by far the most abundant and diversified land-living creatures throughout all that time. The life span of any group depends on its ability to cope with the vicissitudes of a changing environment. "Change with me or you die," is environment's command to all life. Because the dinosaurs were plastic they could change, and they evolved into bigger, and so far as they were concerned, better forms. But it was this very demand for change that led them into the inevitable pitfalls of overspecialization, and when the greatest of all climatic changes the reptiles had ever seen came at the close of the era, they could not meet the new demands.

At the beginning of the Age of Reptiles, the earth was still in the grip of one of the most effective revolutionary periods in its history—the so-called Appalachian Revolution. On every continent, mountain building and erosion, with the deposition of vast blankets of debris under semiarid climatic conditions, were the order of the times. In North America, relentless compressional forces had formed a great chain of mountains along the eastern seaboard from Nova Scotia to Alabama, of which our present Appalachians are the mere roots. When these forces gave way, the earth's crust snapped and broke all along the eastern flank of this chain, forming a lofty series of blocks and deep basins. This took place in the early Triassic period—so named because in Europe the extensive rocks laid down during that time are clearly separable into three distinct units.

Throughout the later part of this period, the block mountains were gnawed away by erosion, and the basins gradually became filled with debris—deposits which attained a maximum thickness of more than 20,000 feet. Great sheets of molten rock then forced their way up into these deposits and escaped here and there to form lakes of seething lava. These eventually cooled and were buried under more blankets of fine muds.

By the close of the Triassic, this great interior area, flanked by the high ancestral Appalachians on the west and by less lofty mountains on the east, was a nearly featureless plain. That its climate was arid is revealed by the prevalence of mud cracks, indicative of long periods of drying, also by the "desert red" color of much of the deposits, and by other evidence. There were local areas, however, where the climatic conditions were more acceptable and where life was fairly common. Fishes were abundant in the permanent lakes. And the presence of many fossil ferns, cycads, etc., shows that the humid localities were densely clothed with vegetation.

It was in these more favorable places that tiny,



primitive, crocodile-like reptiles and some of the first dinosaurs lived. Fossil remains of these are extremely rare, but their footprints in the rocks are numerous. It seems strange that so many footprints and so few bones have come to light. Probably the regions most suitable for the reptiles were close to the mountains in higher, cooler, wetter places, which have since been worn away by the elements. From these places, the reptiles wandered over the great inhospitable mud flats, leaving the impressions of their feet "on the sands of time." Only an occasional straggler died by the wayside, and it is his bones that we find.

In western North America the setting was not so uniform. Narrow arms of the sea occupied parts of the Pacific Coast region throughout the period, and in these narrow troughs, thousands of feet of marine sediment were laid down. At times, an arm of the sea would extend inland several hundred miles, as far as western Wyoming or even to western South Dakota. As these retreated, streams from the near-by surrounding mountains followed them carrying mud and silt. Our greatest deposit of such continental material laid down in this period extends from Utah to western Texas and in some localities is over 4000 feet thick. The plants and animals likewise were similar to those then in the east. Also, the fossil logs in the Petrified Forest of Arizona tell us that lofty evergreens clothed the uplands of that time.

Nor was all quiet on the western front of North America in regard to volcanic activity. The whole coastal area was peppered with volcanoes that belched forth clouds of ash. Thousands of feet of erupted material make up most of the Triassic rocks of certain islands on the southwest coast of Canada.

Such were the conditions in the world when the dinosaurs were born. But what are dinosaurs? What was their ancestry?

In size they ranged from twelve inches to 80 feet long—or just about one-third of a city block. In the beginning they all walked on their hind legs, and some kept this method of getting around, becoming more and more highly specialized in it. Others became thoroughly adapted to walking on all fours. Still others did a little of both. The skeletons of some were lightly built and bird-like. These were fleet-footed runners—at first flesh-eaters, later herbivorous. Some of the early flesh-eaters evolved into enormous destroyers of life—the Panzer division of the Age of Reptiles. There were gigantic forms that were at home both on land and in water. Others had horned heads or were heavily armored.

The dinosaurs are indeed so diverse that it is difficult to name features common to all. When we think in terms of an 80-foot *Brontosaurus* or a gigantic *Tyrannosaurus,* what we mean by a dinosaur seems perfectly clear. But some of the first types were almost indistinguishable from some members of another very generalized group of reptiles, the Pseudosuchia ("false crocodiles"), which lived in the same period. The evolutionary change from this group to the dinosaurs was so gradual that it is only in minor details that the two can be separated.

One of these borderline cases had hind legs over twice as long as its front ones. For popular purposes let us call this little animal Leaping Lena, for leap it certainly did, and the diminutive Lena is fitting for an animal that was only a foot long. Its scientific name, *Scleromochlus,* is more difficult to remember. The fossil expert examines the shoulder and hipbones in his effort to tell whether an animal is a dinosaur or not. Leaping Lena had no collarbone (clavicle) or

interclavicle—characteristics of the "false crocodiles" that went before. And its hip joint, though incompletely preserved, seems to have had an opening where the thighbone of the leg hinges—a feature that distinguishes almost all dinosaurs—instead of a closed socket. From what is known, Leaping Lena has about an even chance of claiming the title "dinosaur."

While many of the early dinosaurs resembled one another, the group as a whole can readily be divided into two separate lines, distinguishable by the form of the hipbones. These two groups, or orders, have been named to indicate a comparison with lizards on one hand and birds on the other, Saurischia and Ornithischia respectively. In addition to the hip, various other parts of the skeleton, particularly the jaws, teeth, and skull, show distinguishing features. The point is that the two groups, while they are collectively called "dinosaurs," evolved independently from two different lines of "false crocodiles."

Of the first dinosaurs, the Saurischia, or the ones with the more "lizard-like" hipbones, were the more abundant. Their evolution in the beginning was much more rapid than that of the other group, and by the close of the Triassic period they had evolved into three main lines, which continued down to the very close of the Age of Reptiles. These three main lines may be called the Lightweights, the Meat-eaters, and the Land-and-water dinosaurs. *(See chart, 8 and 9.)*

The first Lightweights (Coelurosauria) are the most primitive dinosaurs known. Their skeletons are very delicately and lightly constructed. They all walked on their hind legs, although in one of the earliest from North America the front legs may have shared some of the weight of the body. Their hind legs, especially the lower part, were conspicuously long and slender. Their skulls were equipped with relatively large eye sockets, and many had small teeth of the type adapted for cutting flesh.

Fox-sized dinosaurs

Various types of Lightweights have been discovered ranging in size from no bigger than a small fox to six or eight feet in length. One which seems to make a good grandparent for all the rest is the little animal named *Saltopus,* which roamed the semiarid plains of what is now Scotland. In life he was no more than three or four feet long. His little skeleton has all the features one would expect to find in the ancestor of the later members of this fleet-footed group of dinosaurs, whose evolutionary development, like that of the Meat-eating dinosaurs, became more and more progressive until near the close of the Age of Reptiles.

The Meat-eaters (Carnosauria) are not so named because they were the only dinosaurs that ate flesh but because as a group they were better designed for a carnivorous life than any other and because their members became the most destructive flesh-eating machines of all times. They were the most efficient Panzer unit ever invented. Some, especially the earliest ones, were quite small, but others attained a height of over 20 feet. There is some difficulty in separating some of their earlier members from the Lightweights.

The Meat-eaters all walked on their hind legs, and their front legs were very much smaller, becoming in the later more specialized forms nothing more than meat-hooks. Their grasping hind feet were bird-like. All had big heads with large, dagger-like teeth, the edges of which were serrated, or saw-like. The largest teeth on the side of the mouth were always towards the front.

True Meat-eaters are known to have lived in what is now South Africa and North America, and though not especially abundant, were well established. The one called *Paleosaurus* ("ancient lizard"), which lived in the Old World, seems to have been very near the starting point of all the later forms. This beast was about ten feet long and was already adapted for walking on his hind legs. His skull was deep, his teeth were specialized for cutting, and his hands were of the grabbing type, with large curved claws on the ends of the thumb and the next two fingers.

The most abundant dinosaurs in Triassic times, were the forerunners of the third group, the Land-and-water forms. They were very widely distributed over the world, having been found in North America, the British Isles, Europe, and southern Africa.

Grandfather of the giants

They were small to medium-sized dinosaurs which usually walked on their hind legs, although some spent part of the time on all four. They had long necks and small heads, and their small, pointed or spatulate teeth were still best adapted for eating small reptiles, fish, or soft-shelled invertebrates. Some may also have been partially herbivorous. An eight-foot creature called *Thecodontosaurus* is the earliest known form and is also the most primitive. That is why he makes a good ancestor for all the rest, and for the later giant sauropods. By the close of the Triassic some had become specialized and had departed from the trail of evolution leading to the later giants. *Plateosaurus* ("oar lizard") is one of these—a clumsy animal that got to be 20 feet long. He is known from a number of fine skeletons which were preserved when the animals died in desert regions of prehistoric France and Germany and were covered by wind-blown material.

These dinosaurs are important because they were the most abundant dinosaurs of the Triassic and because they gave rise to the sauropods—the most plentiful group of the next geologic period, some of whose members became the largest of all land-living animals.

Coming to our other main division, we find that the ornithischian dinosaurs, or those with bird-like hipbones, were much slower on the evolutionary pickup than were the types we have just discussed. Almost no trace of them has been found in the first period in the Age of Reptiles—only one fragmentary skeleton, found in Colorado, and footprints indicating three other forms. But they must have been quite varied and widely distributed by then, because at the very begining of the next geologic period their remains show definite specialization into two distinct lines.

The second phase in the rise of the dinosaurs took place in the Jurassic period, which gets its name from the Jura Mountains between Switzerland and France, where marine rocks of that age are some 3000 feet in thickness. Gibraltar, too, stands out today as a

great block of Jurassic limestone that had accumulated on the floor of the sea and was brought to the surface by later fracturing of the earth's crust. Thick Jurassic deposits also occur in India, Australia, southern Africa, and South America.

In North America not a grain of Jurassic rock is to be found anywhere east of the Mississippi River. This great region was being worn down, not built up, throughout the period. Just the reverse was true on the west coast, where sediments accumulated in the long, narrow seas that penetrated inland. In what is today the Rocky Mountain region, conditions were different. A vast trough-like lowland was present, with a long, narrow mountain chain to the west. At first this basin was wind-swept and arid, but as time passed, warm shallow waters came creeping in from the north, ultimately reaching as far south as northern Arizona. Just to the south, arid conditions continued to prevail, and vast deposits of wind-blown sands were piled up. Towards the close of the period, the land tilted up, and great meandering streams flowed sluggishly eastward across this region, spreading out a blanket of muds and sands over an area of 100,000 square miles.

Lands of plenty

Along Jurassic streams such as these, on the margins of seas, and in the swamplands densely clothed with vegetation, the dinosaurs evolved abundantly. There were many other forms of life, too,—flying reptiles, turtles, lizard-like creatures, and crocodiles. More than a thousand different kinds of insects—flies, moths, cockroaches, termites, etc.—are known to have lived there. Primitive mammals became more and more numerous, and the first birds appeared. The seas swarmed with invertebrate life. Some coiled mollusks reached a size of six feet across. Schools of great porpoise-like marine reptiles swam along the shores of every continent.

In these surroundings, the dinosaurs began making their first real evolutionary splurge. The Lightweights became more abundant as time went on. Their best-known representative was a creature that stood about two feet high at the hips and was over seven feet from nose to tip of tail. His name, *Ornitholestes,* means "bird robber"—because at his christening it was erroneously thought that his long, curved foreclaws were suitable for catching primitive reptile-like birds. Closer inspection shows no bird-in-the-hand for *Ornitholestes,* for his much elongated and very compact hand probably couldn't have held a bird even if one had flown right into it. He could have eaten birds though, because his small carnivorous teeth were well adapted for such work.

The true Meat-eaters also became more abundant and more widespread during this period. There was little danger of extinction for these marauders in the lands of plenty. They grew to be nearly 40 feet in length and were well able, with their grasping claws and knife-like teeth, to take on even the largest of the giant dinosaurs, called sauropods.

One of the nastiest of these creatures was the North American *Allosaurus,* whose main diet probably consisted of sauropod steaks. Evidence of his slaughterous feats is written on the remains of a large sauropod found in Wyoming. The spines projecting from the backbone of this victim had been bitten off, and the teeth marks match the teeth of *Allosaurus.*

The Land-and-water dinosaurs, or sauropods, are perhaps the best known to the general public. After all, once you see an animal 80 feet long it's difficult to forget it. Not all were as big as that, however, —some were only 40 feet long. The sauropods were by far the dominant group of the Jurassic period.

Not only were they distinctive in their great size, but they were all short-bodied, long-necked, long-tailed, small-headed, literally almost brainless individuals. One of the largest had a brain no bigger than a man's fist. But these creatures were equipped with an additional "brain" that was twice as large as the real brain and was located in the spinal column in the hips. It wasn't really a brain but a sort of relay-station to transmit to headquarters what was going on behind.

The sauropods walked on all fours, that is, when they walked. It is questionable whether they came out on land at all, because the limb joints were of cartilage instead of firm bone. That a 30- or 40-ton animal could support all his weight on such limbs seems unimaginable. It was more likely that they spent all their time in the shallow water along the shores of lagoons and lakes, walking over the muddy bottoms where at least part of their weight was supported by the water.

Stones to aid digestion

Their heads were relatively small and had peg-like or spoon-shaped teeth wholly unadapted to eating flesh but very serviceable for gathering vegetation. They didn't have to eat as much as one would think, however, since their metabolism probably was low. The type of teeth shows that they could not have chewed their food. What they swallowed was taken care of by their gizzard-like stomachs and stomach-stones, or gastroliths *(see page 12)*.

The bodies of these huge creatures were covered with skin having a surface of small, low tubercles, set close together, but arranged in no regular pattern. Discovery of this was made in 1934 by Dr. Barnum Brown when the American Museum-Sinclair Expedition collected parts of some 20 skeletons from the Howe Quarry near Cody, Wyoming.

Quite a number of different kinds of sauropods have been found. The oldest known member is called *Cetiosaurus,* which means "whale lizard." *Cetiosaurus* is, of course, unrelated to the whales, but is a whale of a big dinosaur, for in length he was around 50 feet. He is a genuine sauropod, though in structure rather a primitive one. He makes, therefore, a good structural ancestor for nearly all the later Jurassic forms.

One of the most familiar of later sauropods is the "Thunder Lizard" (*Brontosaurus*). He got to be around 75 feet in length, but the long "whiplash" ending of the tail accounts for ten or twelve feet of that. He stood about fifteen feet at the hips.

For sheer bulk, the champion dinosaur is *Brachiosaurus,* a native of both North America and eastern Africa. Portions of several skeletons—one rather complete—of this spectacular giraffe-like beast are known. The skeleton is mounted in the Berlin Museum. This specimen shows that the tail is short, but

the animal is still 75 feet long. A unique feature of this dinosaur is that his front limbs are longer than his hind ones, which together with a terrifically long neck made it possible for him to nibble comfortably at leaves 40 feet above the soles of his feet!

A large number of other well-known sauropods living at that time were all thoroughly overspecialized for an aquatic or semiaquatic life in humid climates. Nearly all of them died out at the close of the Jurassic, when earth movements drained their lakes and marshes and the climate became more arid. Survival was possible only for those few lucky ones that lived where the old conditions prevailed. They continued on into the next geologic period, and a few managed to survive to the very end of it, when all dinosaurs gave up the ghost.

The plant-eating dinosaurs that dwelt on land in Jurassic times were the descendants of the earlier ornithischian group already mentioned, which now became more important. There are four main branches of these: the High-armored, the Low-armored, the Horned, and the Duck-billed dinosaurs. The Family Tree on pages 8 and 9 shows when they evolved and how they are related. They were rare at the beginning of this period but branched out considerably towards the end.

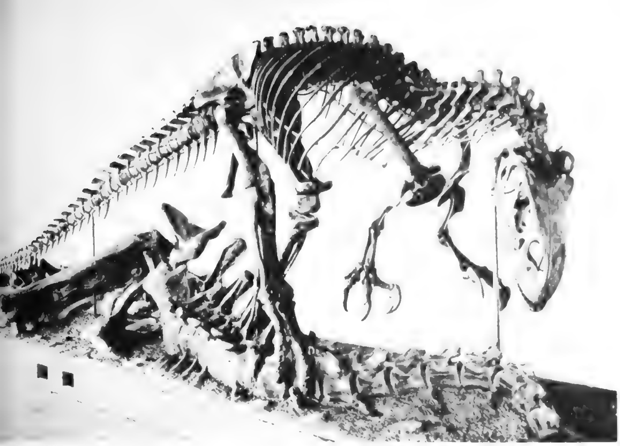
The Duck-billed dinosaurs, quite obviously, had bony duck-like snouts. Some of these dinosaurs, especially the later ones, got to be very large. They all walked on the toes of their hind feet, although certain ones occasionally touched the ground with their hands. The whole skeleton of these animals was massive. The head was relatively large and was equipped with numerous teeth of the chopping type. *Camptosaurus* was the most common and widespread representative of the Duck-billed group at the end of the Jurassic.

The High-armored dinosaurs or Stegosauria got away to a good start at the very beginning of the Jurassic and became a typical feature of the landscape during this time in the earth's history. The earliest one we know, *Scelidosaurus,* had several rows of tubercles and keeled plates along the back, and a row of fairly large vertical plates down along the top of the tail. But his coat of mail wasn't nearly as fancy as that of his descendants, who really went in for decorations. The stegosaurian style-setter was *Stegosaurus* himself, typical of North America late in this period,and of occasional occurrence in England.

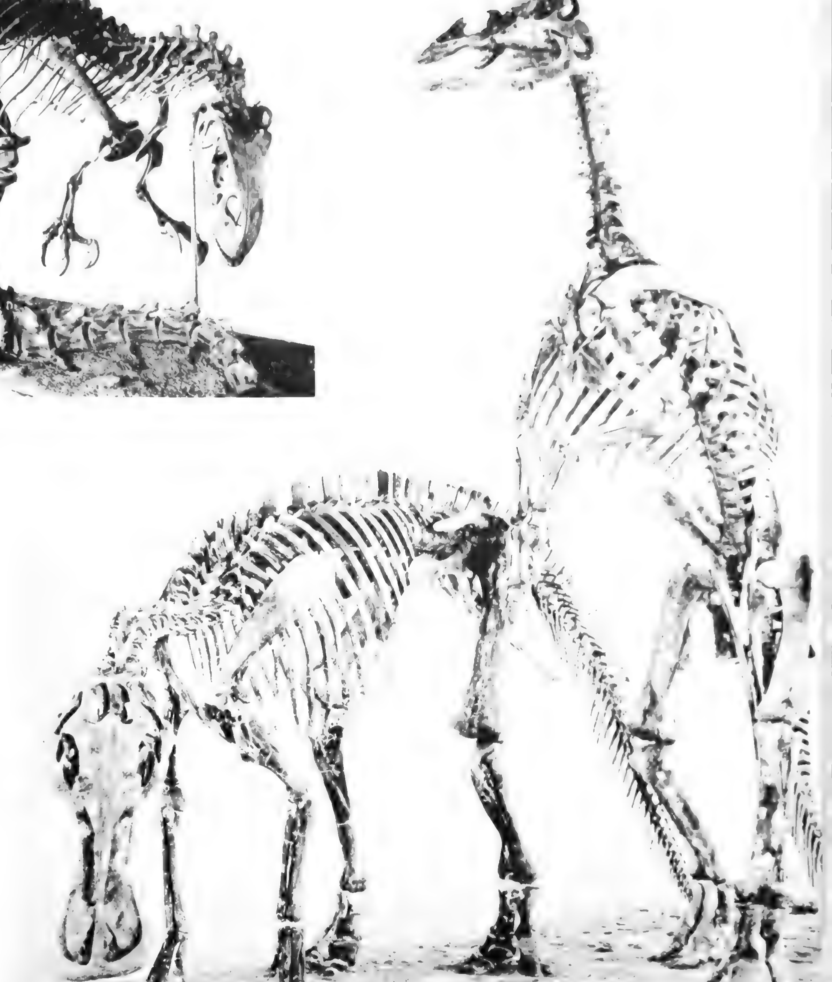
Stegosaurus got to be 30 feet long, had a little head and a short tail. That little head of his had very little in it, but like the sauropods, he had a second "brain" in his hindquarters—and what a "brain"! In some it was 20 times larger than the regular brain up forward.

A double row of large plates projected along the middle of the back and onto the tail, at the end of which rose two pairs of long spike-like spines. Of what service these ornaments were to the animal is not certain. Many suggestions have been made. It has even been proposed that they might have acted as a sort of roofing or self-invented shade to protect the reptile from too much sunlight when forced out of the abundant vegetation. They certainly were a protection against attack when dictator *Allosaurus* and his crew took on *Stegosaurus.* And the spines at the end of the tail must have been very effective ankle-busters in combat. Gaudy and homely as these structures seem to us, we may assume that they were attractive to a stegosaurette back in the Jurassic jungles. Furthermore, it must have taken a shrewd Meat-eater to spot one of these creatures with its big, and probably greenish, leaf-like superstructure, half-hidden in one of those Jurassic marshes or in the bush along one of the lakes.

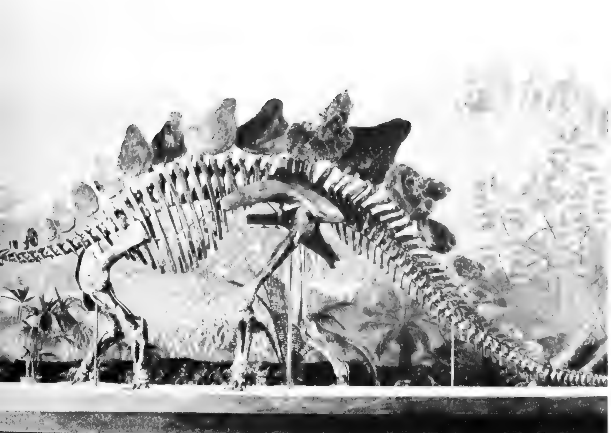
By the end of the Jurassic period, the dinosaurs had risen to unquestionable ascendancy. But the Age of Reptiles was not yet over, and with further environmental changes in store for them, the dinosaurs were destined to have an even greater evolutionary development. With the closing of the period, the earth once again began to tremble. And in their effort to meet new environmental conditions, these most sensational animals of all time entered upon some of their most surprising adventures in the remaining 60 million years of the Age of Reptiles.



A Carnivorous Dinosaur and its Prey *(Allosaurus* and *Brontosaurus).* Though not as huge as *Brontosaurus,* the *Allosaurus* of the Jurassic was a formidable carnivorous reptile which may have preyed upon its larger contemporary.



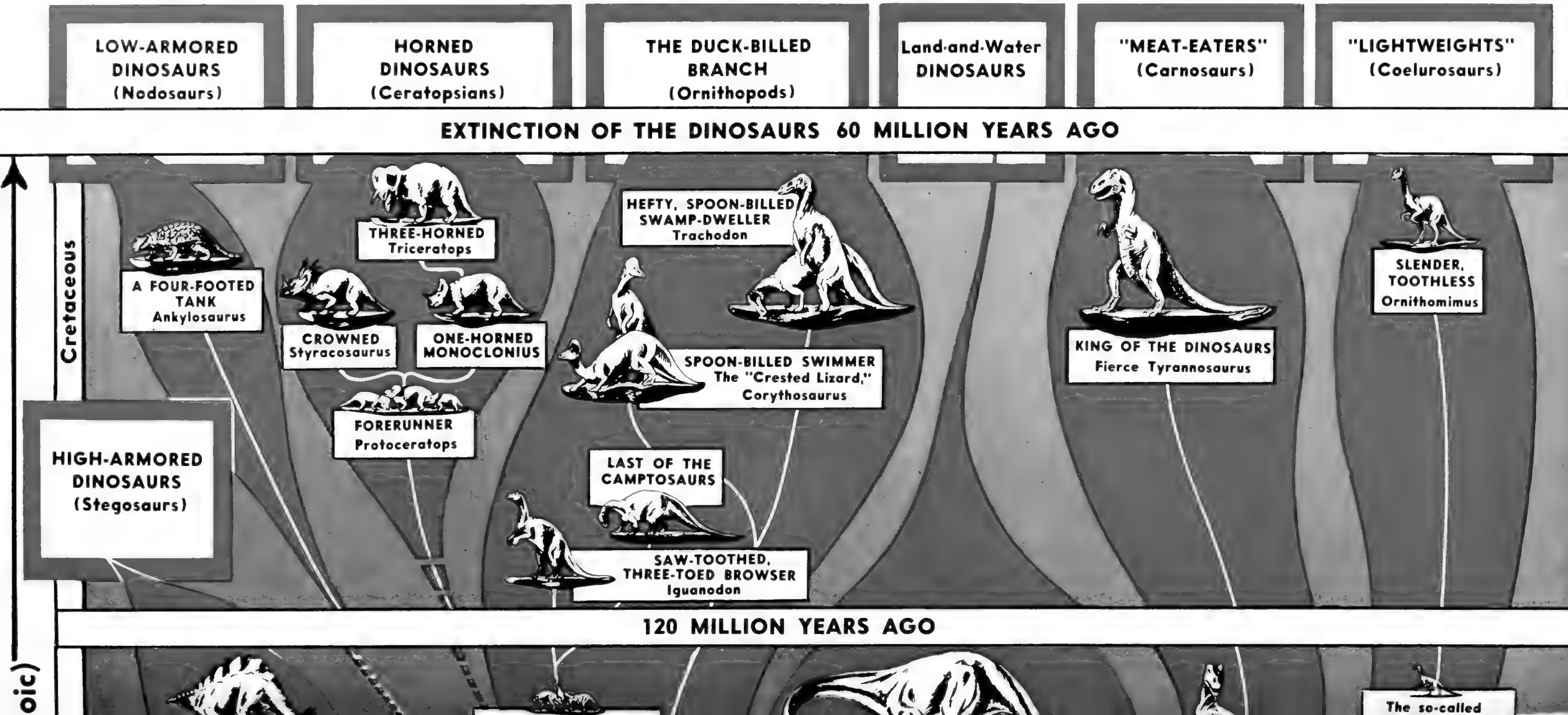
The Duck-Billed Dinosaur *(Trachodon).* These remarkable herbivorous dinosaurs of the Cretaceous Age had a curious duck-like bill used in gathering aquatic vegetation.

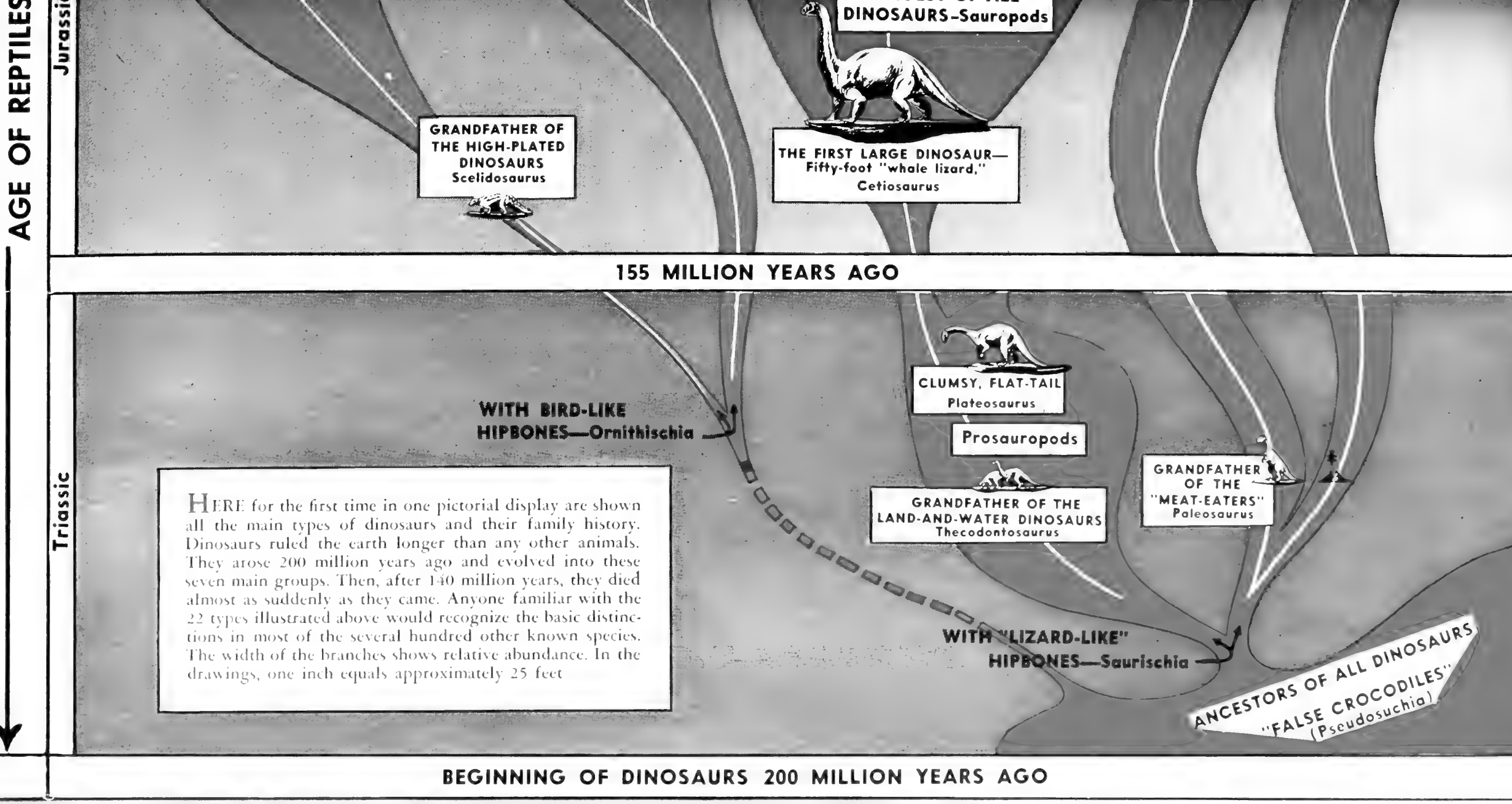


Stegosaurus, a strange armored dinosaur of the Jurassic Period, characterized by its extremely small head, the huge bony plates on its back, and the tail armed with long, sharp spines.

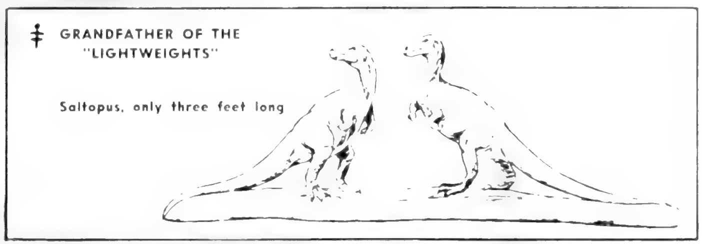
Family Tree of the DINOSAURS

By Barnum Brown *and* Erich M. Schlaikjer





HERE for the first time in one pictorial display are shown all the main types of dinosaurs and their family history. Dinosaurs ruled the earth longer than any other animals. They arose 200 million years ago and evolved into these seven main groups. Then, after 140 million years, they died almost as suddenly as they came. Anyone familiar with the 22 types illustrated above would recognize the basic distinctions in most of the several hundred other known species. The width of the branches shows relative abundance. In the drawings, one inch equals approximately 25 feet



Drawn by
Alastair Brown
from models by
Georgia Mary Whitman

Natural History Magazine, December, 1941

THE

In the foregoing article we have seen some of the earliest known representatives of this remarkable group of reptiles and have envisioned the conditions that surrounded them during the first two chapters in their history, through the Triassic and Jurassic periods. The third and final chapter of their life story took place during the Cretaceous period, which lasted for 60 million years. During this time revolutionary earth movements caused portions of the North American continent to rise still higher above the sea, thus reclaiming submerged areas.

The strictly water-living sauropod dinosaurs, which had been so abundant in North America during the preceding period, continued for a short time in the north, but early in the Cretaceous period they died out there owing to climatic changes.

In the area that is now the southern United States, however, climatic conditions favorable to their existence continued, and there they persisted almost to the close of the Cretaceous period—millions of years after they had become extinct in the north.

Back in Jurassic times a typical lakeside scene would have exhibited more of these huge sauropods than any other creatures—slow-moving, cold-blooded reptiles that required little food in comparison to their size. But in the Cretaceous period the glades and swamps were inhabited by more varied types, among which the Duck-billed and the Horned dinosaurs were the most numerous.

TYRANT KING OF THE DINOSAURS, *Tyrannosaurus rex*. This largest flesh-eating animal that ever walked the earth had a sharp nose for blood and carrion, but the days of his rule were numbered

Drawing by
ALASTAIR BROWN

LAST DINOSAURS

By BARNUM BROWN

Curator of Fossil Reptiles, The American Museum of Natural History

It was the era of spectacular armaments, but even Dictator Allosaurus and the four-footed tanks went down before world conditions with which they could not cope

The beginning of the Cretaceous period marked the advent of a highly diversified plant life. Whereas the only type of flowering plants known in the previous two periods were the cycads, the landscape now developed a flora almost as varied and abundant as it is today. Undoubtedly this change in the vegetation influenced the diversification of dinosaurian life during the Cretaceous period.

It is impossible to speak of dinosaurs—a great order of creatures which existed for so many millions of years—without becoming philosophic. They were one of Nature's greatest experiments—a bold venture along new lines. Various forms were tried out, under various circumstances; but after 140 million years, all were thrown into the discard. "All?" you may ask. "Might not some explorer discover descendants of the dinosaurs living today in some hidden corner of the world?" The thought is a romantic one, but I am sorry to say the chances are nil.

Most extinct creatures have left some living descendants or not too distant relatives that give definite clues to their peculiarities and habits, but the dinosaurs left none. As we know them today they suddenly appeared in the Triassic period, 200 million years ago, and they as suddenly ceased to exist near the close of the Cretaceous, 60 million years ago. Our real knowledge of the group goes back only 100 years, when footprints were first found in the Connecticut Valley and were thought to be the tracks of Noah's raven. Since then hundreds of skeletons and incomplete remains of dinosaurs have been classified and exhibited in museum halls, yet every active institution has in its storerooms countless specimens—single bones, fragmentary bones, and teeth—as yet unclassified, of doubtful identity, or entirely new. Many of these, insufficiently understood and too doubtful to bring to light, will remain unpublished until we can learn more definitely of their relationships.

Dinosaurs are so remote from the experience of most people that perhaps the best way to make these dry old bones come to life is to examine the equipment with which Nature endowed them, and to see them perform. If we can see what made the wheels go round, instead of merely pigeonholing them with names and classifications, we may know better what it would have been like to be a dinosaur.

Several hundred species of dinosaurs have been determined; yet we know that these represent only a fraction of the once numerous population. It is indeed a poor season when an expedition does not uncover one or more new species. Realize that all of the combined exposures of dinosaur-bearing rocks represent only a tiny percentage of the accumulated sediments laid down during dinosaur days. Where the dinosaur-bearing beds are being weathered away, each rain may expose specimens previously covered. So we search the same areas year after year and find new specimens. Classic fields will continue to reveal new forms as erosion goes on. And new beds are continually being discovered.

In favorable places dinosaur footprints are found in great numbers, and they are so varied in form that only a few general types have been identified as belonging to creatures whose skeletons we already know. Literally thousands of tracks have been found in the Triassic rocks of the Connecticut River Valley, representing a great many distinct forms. Yet only twelve species of dinosaurs are known by incomplete skeletons from these same rocks.

The rarity of dinosaur bones in this welter of tracks is one of the great mysteries of the past. Possibly it is to be explained on the grounds that the bones were too delicate for preservation in these particular sediments. In spite of their size, the bones of living dinosaurs were probably as delicate as are those of our present-day salamanders. As fossils, the large bones of dinosaurs are extremely heavy, but most of the weight is made up of rock that fills the cavities in the bones—cavities once filled with air. Changed to stone as they are now, it is difficult to appreciate their original lightness and fragility.

In other places, where dinosaur remains were mingled with great masses of vegetation, the skeletons probably were destroyed by humic acid generated during the changes brought about in the formation of coal. Notable examples of this kind were found by the American Museum-Sinclair Expedition of 1937 in the coal fields of Wyoming.

Few skeletons of young dinosaurs

Another mystery connected with dinosaurs is that we find so few bones and skeletons of the young as compared with the vast number belonging to adults. There are only a few cases on record where we can say definitely that the individual was a young animal of a kind known by adult skeletons. Water was necessary for the bones to become fossilized, and it was also essential in the life of the vast majority of dinosaurs. Even semiaquatic creatures of today, such as turtles and crocodiles, lay their eggs away from water. And it has been satisfactorily determined that the egg-laying dinosaurs deposited their eggs in sand

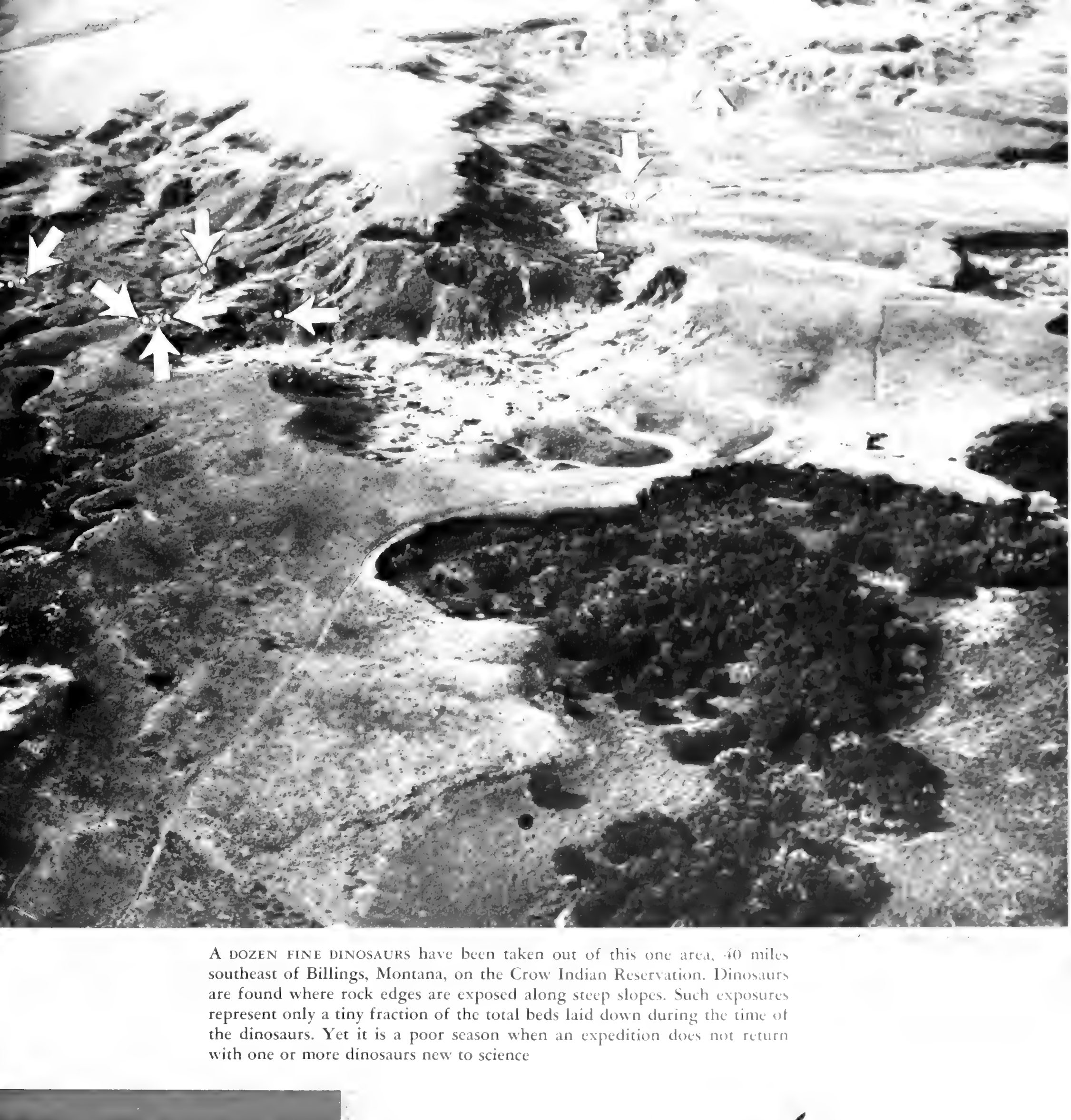
A DINOSAUR TREASURE GROUND

Drawing by Erwin Christman

(Above) A DINOSAUR that looked like an ostrich: *Ornithomimus,* one of the last Lightweights. This toothless animal, which departs so widely from the popular idea of a dinosaur, was about 6 feet tall and may have lived on crustaceans

(Below) GIZZARD STONES. Various kinds of dinosaurs probably swallowed stones which served to grind their food. Here a large number of small stones can be seen among the ribs exactly as found in a small dinosaur in Mongolia

AMNH photo



A DOZEN FINE DINOSAURS have been taken out of this one area, 40 miles southeast of Billings, Montana, on the Crow Indian Reservation. Dinosaurs are found where rock edges are exposed along steep slopes. Such exposures represent only a tiny fraction of the total beds laid down during the time of the dinosaurs. Yet it is a poor season when an expedition does not return with one or more dinosaurs new to science

HE OLDEST unaltered animal substance nown: skin at least 120 million years old. he left-hand piece shows the actual skin f a dinosaur. The other two, though less pectacular as examples of preservation, oth give a clear impression of the surface exture. Sectioned under a microscope, the kin shows a structure similar to the shed kin of a living snake or lizard. Other dinoaurs had distinctive skin patterns like ome of our modern reptiles

Photo by American Museum-Sinclair Dinosaur Expedition of 1934

away from water, where they were hatched by the heat of the sun. If the very young died, perhaps they died where there was no mineral-bearing ground water to fossilize their bones.

Other forms, such as the large sauropods, probably gave birth to living young. Among this group there are more specimens that probably represent young animals. The great number of individual remains found together in favorable places and in definite growth stages indicate multiple births as in living reptiles.

How long did dinosaurs live? We can only guess. Their growth and development was probably rapid in spite of their sluggish habits and small consumption of food.

The oldest unaltered tissue

Our efforts to discover what these creatures were like in life are, of course, hampered by many obstacles resulting from the millions upon millions of years separating us from them. But we are fortunate in knowing even the texture of their skin in some cases. Among the huge long-necked, long-tailed sauropods, a section of tuberculated skin pattern was found on a single leg bone in England; and in the great Howe Quarry in Wyoming we found isolated loose patches of skin impression all over the quarry—indeed, impressions not only of the skin pattern but the actual skin substance itself. This has been sectioned and studied under the microscope, and it shows a structure similar to the shed skin of a snake or lizard. This is the oldest unaltered animal substance known, approximately 140 million years old. The surface of this skin is composed of small, low tubercles or bumps, the size of a pinhead, not overlapping as in the scales of fishes or snakes or in the mosasaurian (marine) reptiles. There is no evidence of a definite pattern, nor can we be certain which type of animal this skin covered. But as most of the remains were of barosaurs, the skin in question presumably came from these sauropods—animals that were 50 feet long and twelve feet high, with heads a foot long and brains that weighed an ounce!

Our knowledge of the skin of the Duck-billed dinosaurs—the most numerous of the Cretaceous dinosaurs—is much more specific. We have every authority for saying that the different species could be distinguished by skin pattern as clearly as are the different genera of modern lizards. Many specimens are preserved with the skin impressions immediately overlying practically all parts of the body. So completely do the skin impressions "clothe" two bodies that they have been called mummies, although no part of the actual skin substance was preserved.

Among the Duck-billed dinosaurs, the different areas of the body had different skin patterns—tubercles of characteristic size and shape. Large rosettes were distributed in rows down the belly and upward over the back, with the individual tubercles larger and more uniform in general character over all the tail surface. This wrinkled skin was evidently so tough that when the carcass was covered with soft silts during burial it resisted decomposition for a long time while the silts were hardening, thus forming a clear-cut impression. Later the skin substances decomposed and the impressions were preserved with exact fidelity as to form and pattern. In other species we find uniform impressions without pattern development. At present we are of the opinion that the crested Duck-billed dinosaurs lacked definite pattern arrangement and that some of them may have been variously colored like modern lizards. Probably this group lived for the most part in the water. Sometime in the future when a sufficient number of Duck-billed specimens have been recovered it will be possible to assign definite skin designs to the various species and to identify the creature by them even as we do now by skeletal features.

Among the Horned dinosaurs of the same period several specimens have been recovered with patches of skin impression preserved, and in these forms there is also a definite series of rosette-like patterns on the sides of the belly.

The Low-armed dinosaurs, such as *Ankylosaurus* ("stiff lizard"), were huge, slow-moving armored "tanks," some of them fifteen feet long, five feet high, and six feet wide. The back and sides of these animals were covered with rows of plates running crosswise and lengthwise like those of modern alligators and crocodiles. An epidermis or outer skin, which was similar in form and pattern, covered these plates. Plates of smaller size, varying in form and size so as to permit movement, covered the belly and legs. This numerous and varied group of dinosaurs resembled enormously enlarged, drawn-out "horned toad" lizards.

Gizzard stones

Chickens and other gallinaceous birds swallow stones which serve the purpose of grinding their food in the gizzard or pro-stomach. Some extinct animals such as plesiosaurs regularly followed this same practice, and there is no doubt that certain types of dinosaurs also swallowed stones. A skeleton of an orthopod dinosaur from Mongolia now in the American Museum has 112 stones preserved within the body cavity. With another specimen—one of the large sauropod dinosaurs of the type of *Barosaurus* —seven highly polished stones were preserved with the vertebrae, and it is practically certain that these stones had been in the dinosaur's body when it died.

In some fields where dinosaur skeletons are numerous, as in the Lower Cretaceus beds of Montana, we find literally thousands of highly polished stones that probably were regurgitated by dinosaurs after the stones became rounded and therefore no longer useful as grinders. None of these highly polished stones were found in the body cavities of skeletons from the same beds. We did, however, find such stones while excavating one of the skeletons, and they show the same high polish as those found exposed in the surface layers. In another place where a great number of skeletons were found together, in the Howe Quarry of Wyoming, there were 64 well-polished stones under the shoulder blade of one of the large skeletons.

These are a few examples in which the implication is quite conclusive that some sauropods, as well

as other types of dinosaurs, had the habit of swallowing stones as an aid in digesting food. Our difficulty, however, is to explain the high polish found on the supposed stomach stones (gastroliths), because among the modern birds, hard objects such as glass are etched rather than polished in the gizzard. In our opinion the polishing took place by some unknown process in the alimentary canal of these dinosaurs. The highly polished stones are invariably found in rock layers that contain dinosaur skeletons and they are not found elsewhere.

The teeth of dinosaurs shed much light on their feeding habits. Some dinosaurs like *Ornithomimus* ("bird mimic") were actually toothless and they may have fed upon crustaceans. Those that fed exclusively on flesh were provided with sharp, dagger-like teeth, some of which were smooth on the borders, others serrated.

As among many living reptiles new teeth were grown to replace those broken or lost throughout the life of the individual. The plant-feeding Horned dinosaurs shed their teeth and replaced them with new ones as soon as the enamel-surfaced crowns wore off.

Two thousand teeth

In other groups like the plant-eating Duck-billed dinosaurs, the feeding habits were evidently quite different, since they were provided with a highly complicated tooth system. Some of them had more than 2000 teeth at a time, arranged in the jaws like rows of cartridges in a gun-clip. The teeth were all curved and had enamel only on the outside of the upper teeth and the inside of the lower teeth. Thus the enameled surfaces acted as the blades in a pair of scissors for sectioning the food. As the enameled surface wore down, new teeth came into place at the cutting edge, and the worn roots functioned as a grinding surface. This complicated tooth arrangement must have served a specific purpose, and it seems probable that these animals fed on some highly siliceous kind of plant like "horsetail" rushes, which were abundant during the Cretaceous period.

We marvel at the comparatively small brain in all of these huge creatures. Some of the largest bodied sauropods had the smallest brains, and none could have exceeded ten ounces in content—only about one-fourth the size of a man's.

Casts of the brain cavity have been made from several kinds of dinosaur skulls. Even the semicircular canals, the "balancing organs," have been determined, and in a few cases we have explored the pituitary cavities. It seems probable that dinosaurs as a race were hyperpituitary cases. This, in a measure, may account for their great diversity in form and sizes.

The brain cast of *Tyrannosaurus rex*, "tyrant king," the largest land-living, flesh-eating creature that has ever lived, shows a well-developed fore and hind brain and abnormally large olfactory lobes. This would indicate that some of the carnivorous dinosaurs at least, depended largely on their sense of smell when searching for food, and that they were carrion feeders as well as killers.

Dinosaurs were more plastic than any group of living or extinct creatures of which we have a definite record, and their capacity to meet changing conditions may account in part for their long existence. Most lizards of today can regenerate a new tail if they lose the original one—but there will be no bone in this replacement. The long-tailed sauropod dinosaurs, however, could regenerate not only the soft tissue of the tail but the tail bones as well. One of the sauropod specimens found in the Howe Quarry at Shell, Wyoming, demonstrates this ability, for 21 vertebrae at the end of the tail were "replacements." Several other similar examples of regeneration were found in this quarry.

What happened to the dinosaurs?

Dinosaur remains are found practically over the entire world, but these animals did not get up and travel from one section to another as mammals do when seeking a change of environment. We picture their migration as a slow, gradual dispersal and encroachment into favorable bordering regions—a movement comparable to wavelets where a stone has been thrown into a pond.

The dinosaur race perished all over the world at approximately the same time, near the close of the Cretaceous period. There has been much speculation as to the cause of their extinction, and several untenable theories have been advanced:

1. It has been suggested that a series of sudden cataclysms such as volcanic outbursts may have exterminated them. But many of the latest survivors died too far from volcanic regions for vapors or even wind-borne ashes to have harmed them.

2. Another supposition is that mammals—progressive newcomers on the earth—might have destroyed the eggs of the dinosaurs. But many kinds of water-living dinosaurs undoubtedly gave birth to living young and were safe from predatory land creatures.

3. Finally it has been argued, that the climate became too hot for the dinosaurs. Modern reptiles, to be sure, cannot stand extremes of heat,—but the plant life at the time of the last dinosaurs does not indicate such temperatures.

The best explanation of the extinction of the dinosaurs follows other reasoning. Dinosaurs had become highly specialized creatures. The plant-eaters were restricted in their feeding habits to certain types of vegetation. When, through regional elevation toward the close of the Cretaceous period, lakes and swamps were drained and plant life changed or became scarce, plant-eaters died out locally, and the carnivores went with them. For they could not migrate rapidly enough to new, favorable places or adapt themselves to a radically and rapidly changing environment.

After all, why should we criticize any group of animals for giving the earth over to other creatures after 140 million years of supremacy? They were amazing creatures, to say the least, and the mysteries still surrounding them will continue to give zest to one of the most absorbing branches of scientific exploration for many years to come.

The Film of Life

The Vertical Extent of Living Things on the Earth

By G. MILES CONRAD

Assistant Curator, Department of Comparative Anatomy

Guide Leaflet Series No. 109

HE AMERICAN MUSEUM OF NATURAL HISTORY

Issued under the direction of the
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Roy W. Miner, *Chairman*

THE

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THE FILM OF LIFE

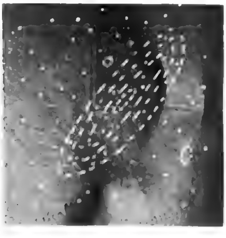
By G. Miles Conrad

Assistant Curator, Comparative and Human Anatomy, The American Museum of Natural History

Among all the strange things that men have forgotten, G. K. Chesterton once commented, the most universal lapse of memory is that by which they have forgotten that they are living on a star. In all the measureless realms of space, our planet is the only particle of matter supporting any known life. And of this celestial particle, only the thinnest surface film manifests that miracle of which you and every tiniest living cell are a part. The final mystery of life will perhaps never be solved. Whence

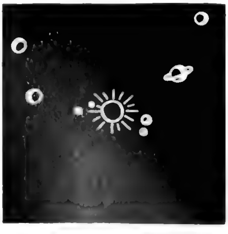
Scattered through the infinity of space are countless spiral nebulae, star systems so vast as to dwarf the solar system to insignificance. [illegible] out in space we would have [illegible] most powerful tele[illegible] [illegible] all part of the [illegible]

1



see our sun, with its nine planets, of which the earth is one. Singling out the earth, we move closer and see that a hazy atmosphere clings to the surface of the globe, through which we recognize

2

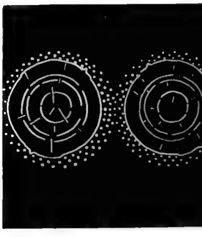


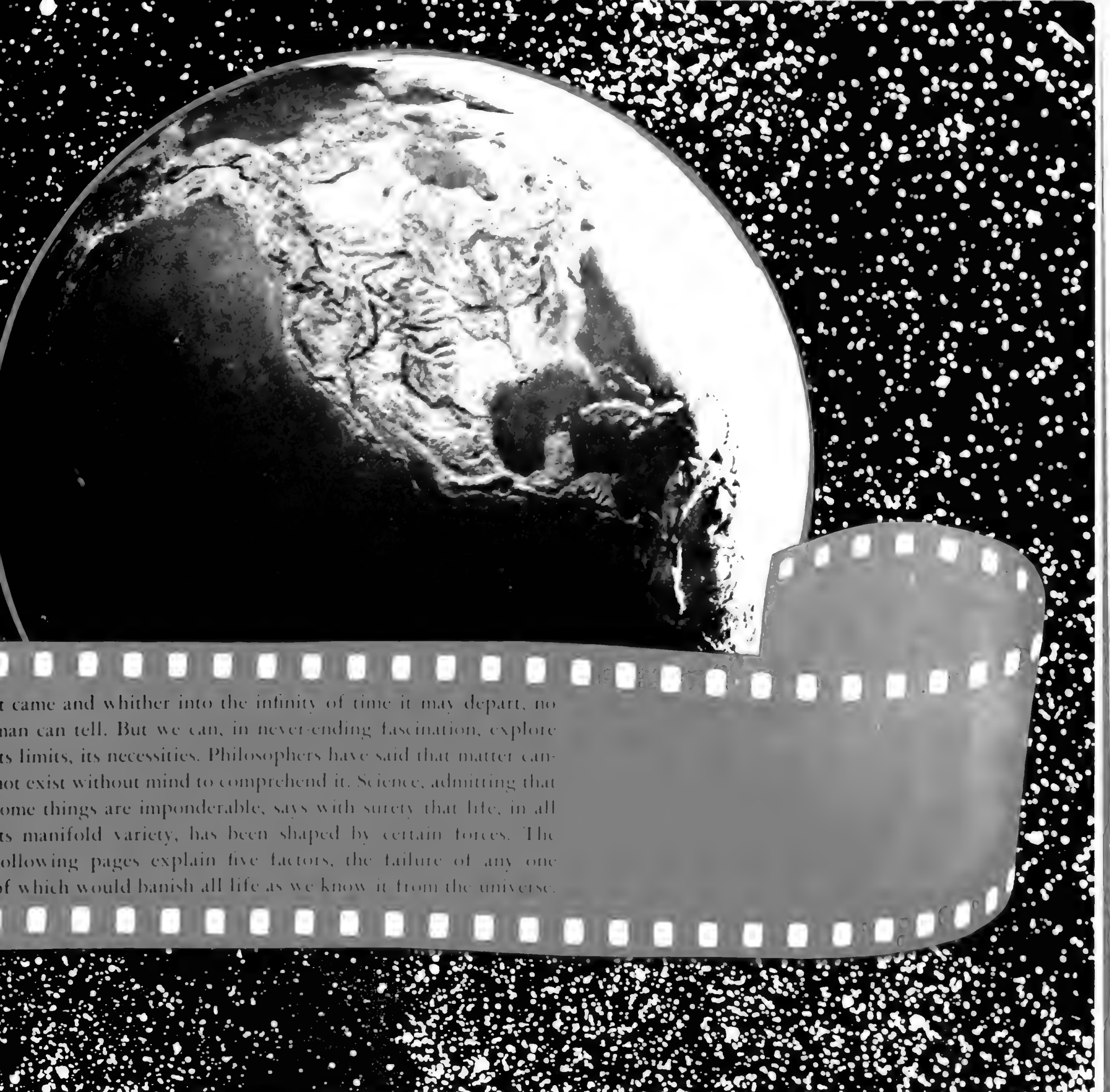
the continents. Solid land makes up $\frac{1}{3}$ of the surface, water $\frac{2}{3}$. Crawling over and clinging to the sides of this whirling planet is life. The faint green of plants covers large areas; movement of animals is almost everywhere.

3

If we were to cut the earth in [illegible] in our cosmic laboratory, [illegible] would find that the liquid [illegible]face is but the thinnest coat and that the solid portion is [illegible] true core. A few feet und[illegible]ground all life ceases.

4

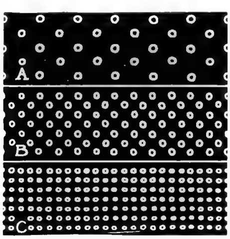




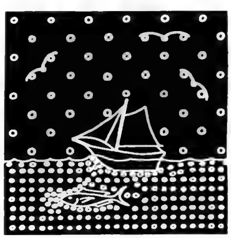
t came and whither into the infinity of time it may depart, no man can tell. But we can, in never-ending fascination, explore its limits, its necessities. Philosophers have said that matter cannot exist without mind to comprehend it. Science, admitting that some things are imponderable, says with surety that life, in all its manifold variety, has been shaped by certain forces. The following pages explain five factors, the failure of any one of which would banish all life as we know it from the universe.

enlargement of the edge of r earth section where air, land, d water meet, shows that life confined to a thin "film" about miles in depth. This is the ly realm containing any known e in the vast immensity of ace.

6 We see life in the air (atmosphere), in the water (hydrosphere), and on the land (lithosphere). The molecules making up air (A) are relatively far apart; those of water (B) closer; and those of the lithosphere (C) quite solidly packed.



7 The closer together the molecules are, the greater the supporting power, but also the greater resistance to an object moving through the medium. It is harder for a bird to keep from falling than a fish, but it can travel faster.



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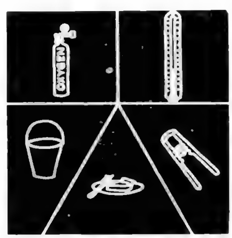
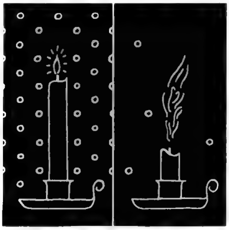
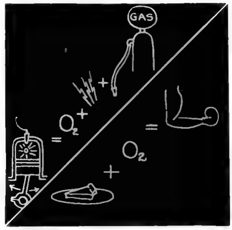


9 Oxygen, as a colorless and tasteless gas, is found almost everywhere on earth. Sometimes it is in combination with other elements but, fortunately for animals, it is commonly found "free" as high and as deep as life can penetrate.

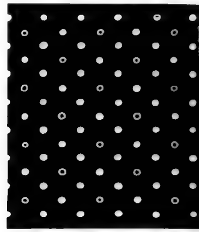
10 Many life processes are "oxidations," in which oxygen combines with other substances in the body to produce energy and heat. A candle flames brightly in a steady supply of oxygen but flickers and dies when the oxygen is exhausted.



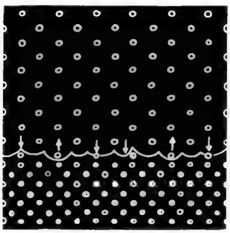
11 Just as the fuel in an engine is ignited in the presence of oxygen to produce energy, so does the combustion of food in the body produce muscular power. Without oxygen, protoplasm — the basic substance of life—disintegrates.



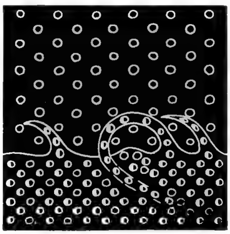
12 At sea level the normal co
of the air is 20 per cent ox
and 79 per cent nitr
plus small traces of
gases, such as argon, kry
neon, and so forth. This is
oxygen than is generally ne
by animal organisms.



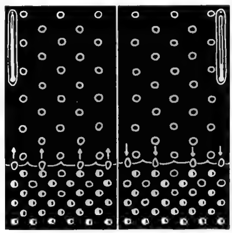
17 Most of the oxygen dissolved in water is derived from the air. It is captured in two ways: by diffusion at the surface and by agitation. Diffusion is a continuous process but too slow to meet the needs of water creatures.



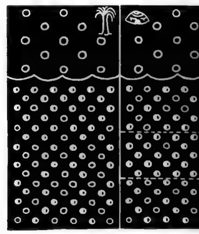
18 But agitation by waves and waterfalls is most effective in supplying oxygen to the waters. Air is captured and pulled under the surface by curling waves. The amount of oxygen water can hold depends on temperature and salt content.



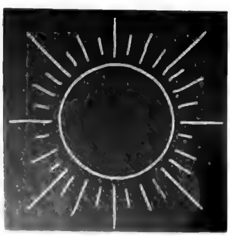
19 Warm water cannot absorb as much oxygen as cool. That is why polar waters support an abundance of marine life, which few people realize. Conversely, water containing a lot of salt cannot hold as much oxygen as fresher water.



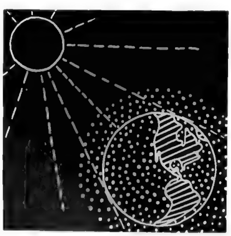
20 The warmth of tropical w
causes them to have relat
little oxygen in the top 1800
But polar waters have
levels: *surface* layer, with m
middle layer, with little;
bottom with a fair amount.
great depths have none.



25 The original source of all warmth on the earth is the sun, even that of the earth's molten core. This is easily checked when we remember that nights are so often cooler than days, a sunny day warmer than a cloudy one.

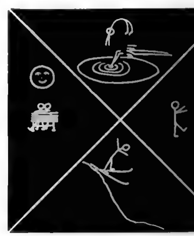


26 Each hemisphere receives the same amount of heat in a year. But where the rays strike vertically they penetrate less atmosphere and are hotter. So, the heat varies with latitude and, since the earth's axis is tilted, with the seasons.

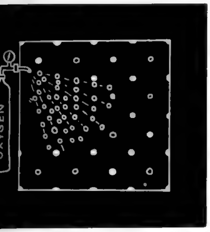


27 Land and water absorb the heat from the sun more readily than air. Indeed, much of the heat from the sun passes through the air to the earth without loss and warms the air only after it has warmed the land and the water.

28 When land and water
warmer than air, they ra
their heat,—causing conve
currents to rise, unequal
sures to develop, and win
blow. These things, coupled
the earth's annual orbit,
our seasons.

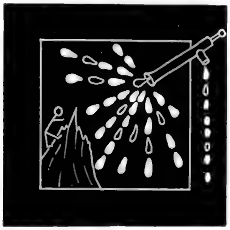


ut under the stress of extreme uscular activity, oxidations will pparently proceed more effi-ently with 3 or 3½ times the xygen normally needed. Exces-vely higher amounts are deadly it are never found in the natu-l environment.



At high altitudes and in great ocean depths, oxygen is deficient. At 18,000 feet there is about half the oxygen there is at sea level, so the heart and lungs must do twice as much work to provide the body with the same amount of oxygen.

14

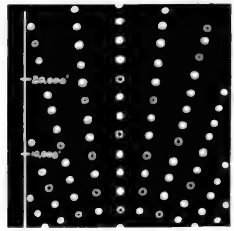


Amounts of oxygen in water vary greatly, and many water animals have developed accessory breathing organs. A number of fishes rise to gulp air. This is dissolved in water, which in passing over the gills yields its oxygen to the blood.

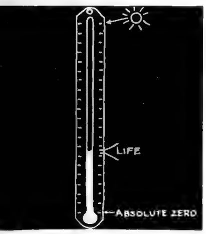
15

The atmosphere is the main source of free oxygen. The heavier gases, oxygen and nitrogen, hover close to the earth and do not occur much over 35 miles above sea level, the absolute upper limit at which life could exist.

16

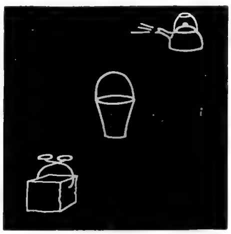


om the heat of the sun's sur-e to absolute zero are 11,291° ; and of this, life is limited to range of 150°, or about 1%. otoplasm, the basic stuff of e, freezes at 23° F. and coagu-es at 158° F.



Under different conditions of heat and pressure, all matter may exist as a solid, a liquid, or a gas. If it is not to solidify or boil away, life must remain within the narrow range of temperatures which limit the thin film of life.

22

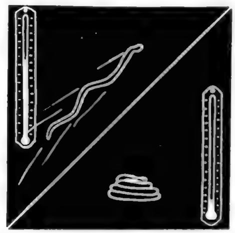


Animals can be divided into two groups: warm- and cold-blooded. The warm-blooded maintain a constant body heat regardless of the weather. This is efficient, because the internal chemical processes can then continue at a constant rate.

23

On the other hand, the body heat of the cold-blooded animal varies with the temperature of its surroundings. Thus, extreme of cold or heat will upset the internal chemical balance, and performance will be inefficient and erratic.

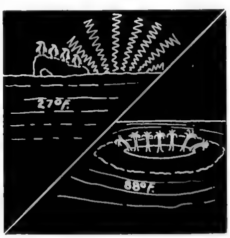
24



e higher we go, the colder it ws, until we reach space ere the temperature is —459° Snow line ranges from near level in the Arctic to 16,000 in the tropics; 3000 feet ve this it is apt to be too cold unprotected protoplasm.

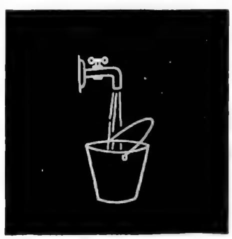
The air does not readily absorb heat and is disturbed by cold and hot winds, hence temperature varies greatly over the earth, from —130° F. to +149° F. But in the oceans, the range is only from 27° F. to 88° F.—*ideal for protoplasm!*

30



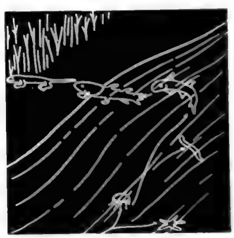
Water is never found in a chemically pure state in nature. It is the "universal solvent" in which are dissolved the foods and wastes of living organisms. There is every reason to believe that life originated in the water.

31



Most of the animals that subsequently evolved moved into an atmospheric environment, but none have ever been able to break completely away from the primordial water environment, even after hundreds of millions of years of evolution.

32



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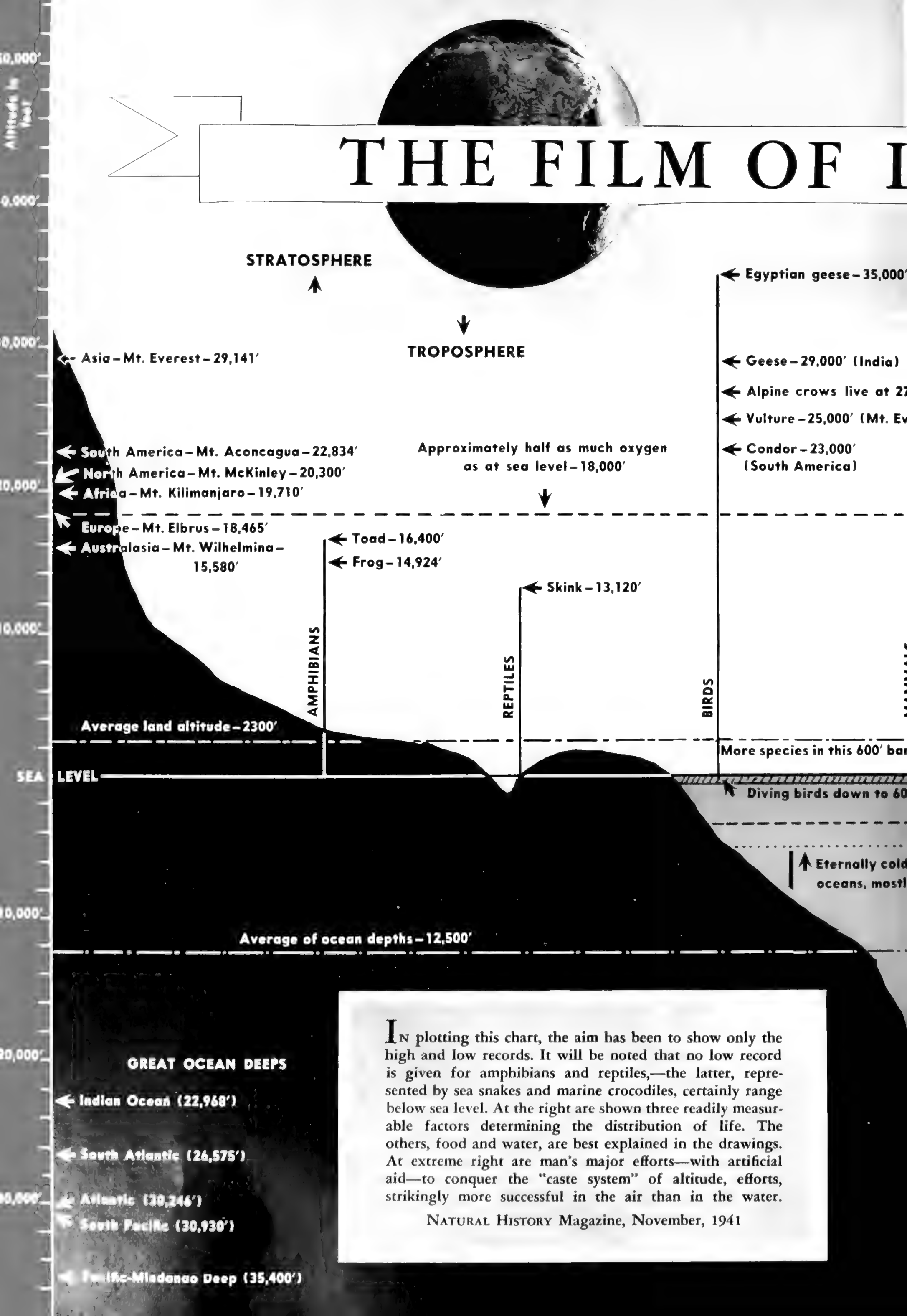
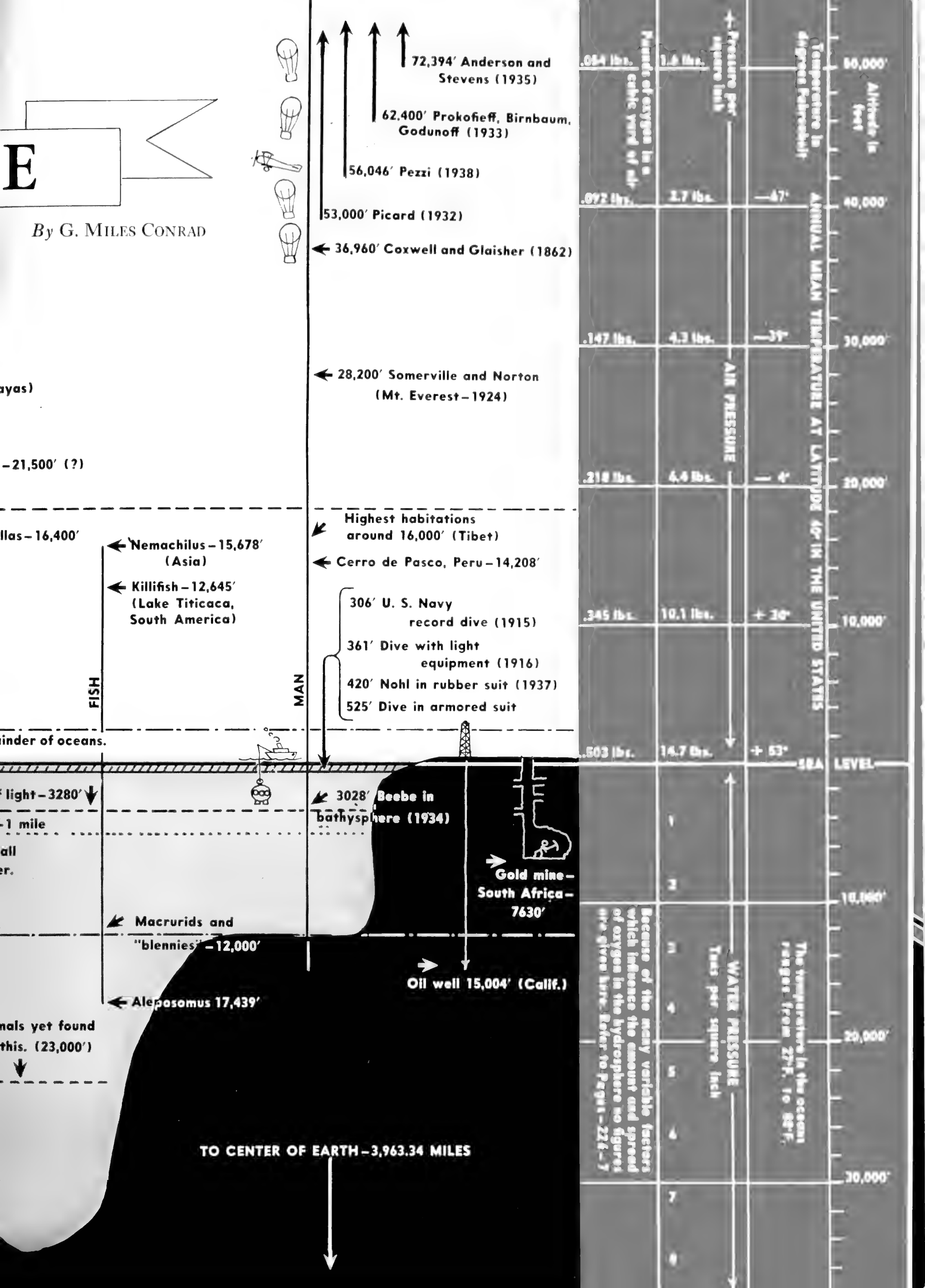


In plotting this chart, the aim has been to show only the high and low records. It will be noted that no low record is given for amphibians and reptiles,—the latter, represented by sea snakes and marine crocodiles, certainly range below sea level. At the right are shown three readily measurable factors determining the distribution of life. The others, food and water, are best explained in the drawings. At extreme right are man's major efforts—with artificial aid—to conquer the "caste system" of altitude, efforts, strikingly more successful in the air than in the water.

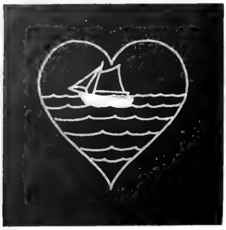
Natural History Magazine, November, 1941

E

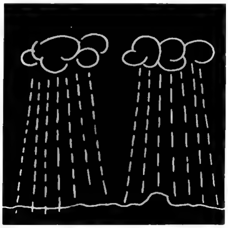
By G. MILES CONRAD



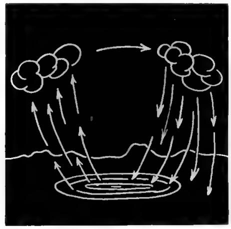
... tied to the primitive ... ent are the land animals ... they carry fluids in their ... which contain a percent... of salt similar to that of the seas. To maintain this internal salt solution, water must be available.



Water vapor is found up to an altitude of twelve miles, above which no animal could possibly exist. This vapor, derived originally from the hydrosphere, is condensed and precipitated in the
34 form of rain and snow.

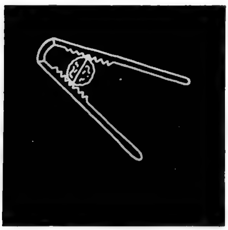


The "sprinkling system" of the atmosphere is a perpetual motion process whereby water taken from the reservoir of the hydrosphere (oceans, lakes, and rivers) is redistributed over both the
35 lithosphere and hydrosphere, aiding life greatly.



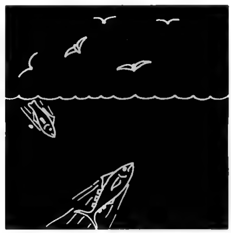
To dwellers in the hydrosphere, water is obviously no problem. Although water is customarily divided into "salt" and "fresh," the distinction is merely a quantitative one, for most fresh waters
36 contain a liberal solution of salt.

Pressure is squeezing or compression; it is the power of our fingers to crack the nut. Life is under constant conditioning by just such squeezing. Normally the internal pressure of an animal equals the environmental pressure.

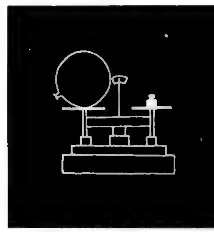


But whether the animal lives in air, water, or on land, when it moves toward the earth's center the pressure increases. And if it moves in either direction too rapidly, trouble follows, for the
38 pressure balance is disturbed.

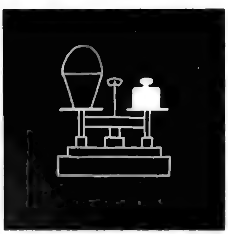
If the animal descends too rapidly, external pressure will try to crush delicate organs. If he ascends too rapidly, the body tends to burst. But only animals that travel up or down quickly need special
39 pressure adjustment mechanisms.



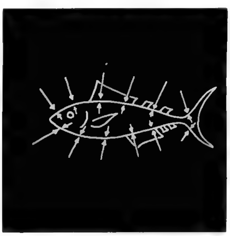
The pressures acting upon lif are of two sources: air and water It is hard to realize that air ha any weight, but at sea level th 150-mile-high column of air ove our heads weighs 14.7 pounds
40 or "one atmosphere."



The higher we go, the lower the pressure becomes, until the vacuum of space is reached. However, a column of water only 34 feet high exerts a pressure of one atmosphere, and a short distance underwater one suffers from the pressure.

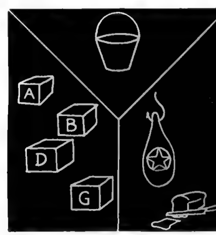


In the great oceanic depths, pressures are so great that they are measured in tons. But it must be emphasized that as long as the internal body pressure is the same as the pressure of the environ-
42 ment, the organism suffers no harm.

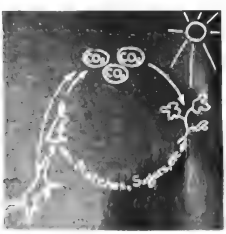


Food must provide, (1) the energy for running the living machine and the material for the generation of body heat, (2) the materials necessary for the renewal of worn-out protoplasm,
43 and (3) materials for growth.

The stuff used by animals fo food is (1) inorganic (water an salts), (2) vitamins, and (3) or ganic materials (proteins, car bohydrates, fats, and oils). In sense, food is sun-energy store
44 by plants and taken by animal secondarily.

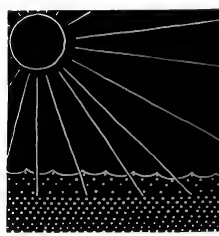


Animals that eat other animals are eating food that has all been manufactured from plants. To flesh-eaters, the rabbit is a food factory, transforming impalatable greenery into meat and exhaling carbon dioxide that the plants can use.



Plant-eaters are limited in their range vertically by the limits of pla life; but flesh-eaters frequently exceed the plant ranges. The ocean is le
46 favorable to plant growth than the land, because sunlight penetrates on shallowly.

Thus ends our "news reel" of *The Film of Life*, with its five actors—Oxygen, Temperature, Water, Pressure, and Food—limiting the vertical range of animals to a thin film in the vast immensity of space.



THE RISE OF MAMMALS

By

George Gaylord Simpson

THE AMERICAN MUSEUM OF NATURAL HISTORY

THE RISE OF THE MAMMALS

After dominating the world for millions of years the Dinosaurs come to an abrupt end and

THE MEEK INHERIT THE EARTH

By

GEORGE GAYLORD SIMPSON
Associate Curator, Department of Palaeontology

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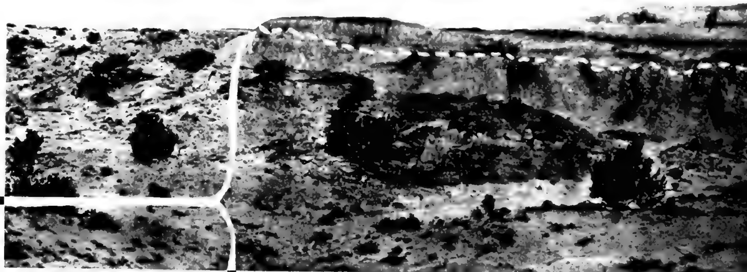
Fifth installment in the story of animal life

After dominating the world for millions of years the dinosaurs come to an abrupt end and—

Th

By GEORGE GAYLORD SIMPSON
*Associate Curator of Vertebrate Paleontology,
The American Museum of Natural History*

(Right) DEAD LINE of the dinosaurs. This dotted line marks the most dramatic and perhaps most important event in the earth's history. It shows the end of world domination by the cold-blooded animals and the rise of the warm-blooded. The scene is an actual fossil ground in New Mexico. Below is seen the shadow of a huge horned dinosaur; above, some of the feeble but sprightly furred creatures that were to take over the earth

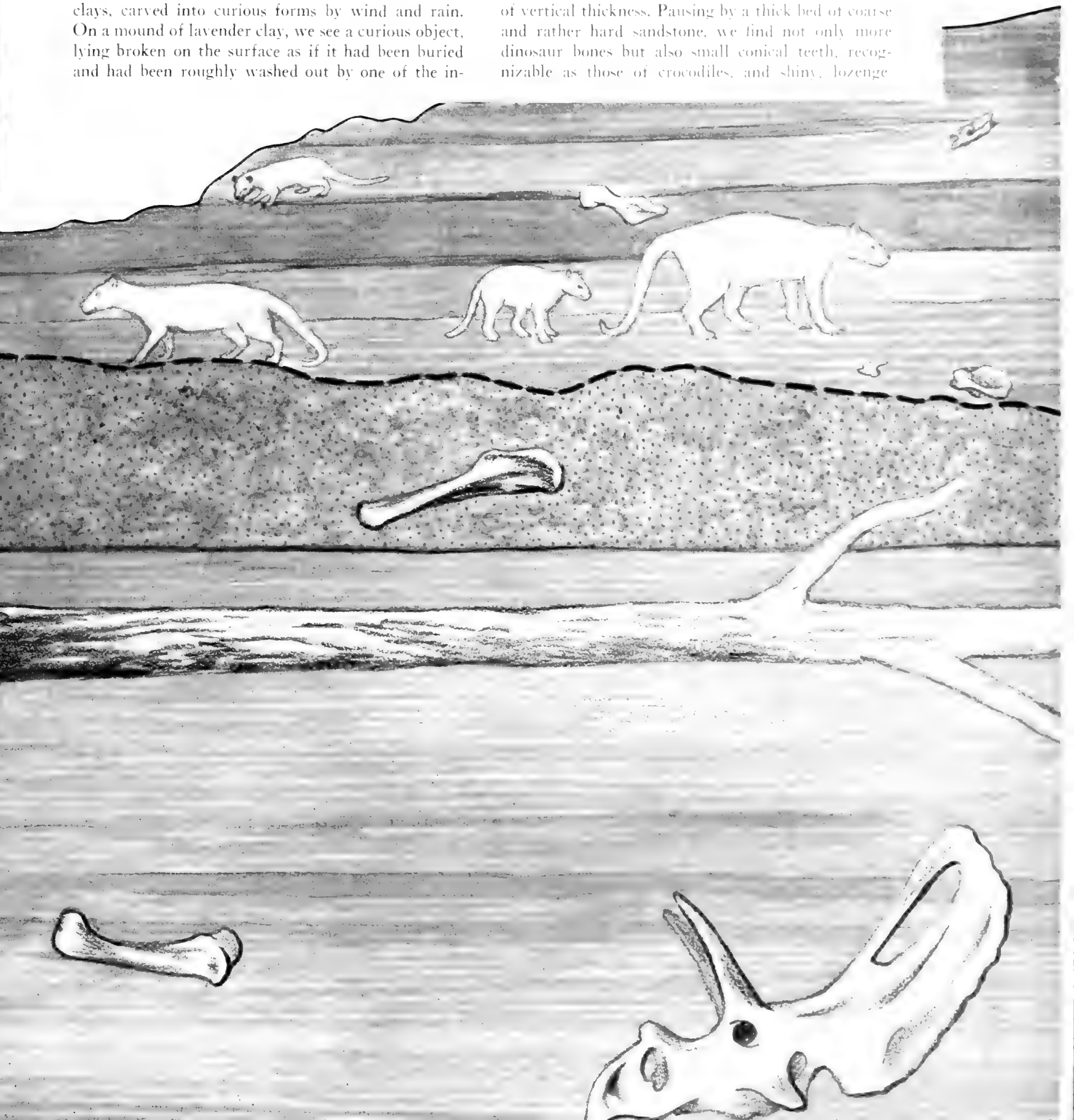


DRAWINGS BY JOHN C. GERMANN

meek inherit the earth

LET us take a walk in New Mexico. We shall start in the northwestern part of the state, near the ancient Indian ruin of Pueblo Bonito, and walk to the northeast, up a sandy arroyo, a watercourse now dry but subject to occasional brief, violent floods. Today the earth is parched under a burning sun, and the scanty sagebrush is dull green and dusty. The sand is blown into ripples and dunes in the bed of the arroyo, but along the slopes are bare exposures of yellow sandstone and delicately tinted clays, carved into curious forms by wind and rain. On a mound of lavender clay, we see a curious object, lying broken on the surface as if it had been buried and had been roughly washed out by one of the infrequent downpours. It looks like a bone, but it is much larger than the bones of any animal now living in the region, it is dark in color, and it is very heavy and hard. It is the fossilized thighbone of a dinosaur.

Continuing our walk up the arroyo we pass a thick series of alternating strata of hard clay and of sandstone, one above the other. At any one point the exposed thickness is only 20 feet or so, but as we go up the arroyo we pass successively higher and higher beds in the series until we have seen several hundred feet of vertical thickness. Pausing by a thick bed of coarse and rather hard sandstone, we find not only more dinosaur bones but also small conical teeth, recognizable as those of crocodiles, and shiny, lozenge



shaped objects almost exactly like the scales of the living garfish, although fossilization has turned them black. Near by is a prostrate tree trunk, 20 feet long and two feet in diameter with the appearance of fresh wood but completely silicified so that sparks fly if we attempt to sink an ax into its inviting surface.

Great amphibious dinosaurs, crocodiles, fishes, and tall trees in this arid, almost treeless desert! These seem like the wreckage of a different world and so they are. These layers of rock entomb remains from the Age of Reptiles, traces of creatures and plants that died more than 60 million years ago. What is now sandstone was then soft sand, and these hard clays were then oozing mud. More sand and more mud piled up until these beds were deeply buried, and as they compacted and hardened, the remains in them were mineralized and fossilized. Later, much later, the seasonal downpours and the constant winds of this now desert region eroded away hundreds of feet of strata and carved into them the channel up which we have walked. Thus their entombed records were brought to light, so that we now find on the surface the relicts of the savage age of dinosaurs, once deeply hidden in the crust of the earth.

We have not only visited a long-lost world. We have also been walking through time, for as we ascended the arroyo, each higher layer in the piled-up series was deposited at a later time than those below. Each step upward may carry us onward ten thousand years in this record of the history of ancient New Mexico. We have traversed one or two chapters of the time of the dinosaurs, in which different species of those terrible reptiles have succeeded each other without, however, ceasing to be similar. Let us continue up the arroyo, which means also to continue later in time, to see what the next chapter of the thrilling serial may be.

The upper surface of the coarse, dinosaur-bearing sandstone proves to be sharply defined and very uneven. Filling the hollows in it is a bed of brilliant red clay above which, extending far above this to the northeast, is another thick series of red, gray, and green clays, with occasional lenticular masses of white or yellow sandstone. It looks as if the older sandstone had been eroded by the elements long ago and that after an interval fresh floods had deposited mud on this exposed surface. This is, indeed, what happened, and the sharp line between the coarse sandstone and

WHERE NOW there is desert, broad rivers meandered over fertile plains at the beginning of the Age of Mammals, 60 million years ago. The climate was moist and mild in the section of New Mexico depicted below, but mammals have since proved themselves so adaptable that there is almost no climate too rigorous for them. Thus they far outstripped the dinosaurs in adaptability. Below, a turtle—old-fashioned even in that day—looks up at a pair of condylarths *(Ectoconus),* prophetic of the new era

1

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1 Most multituberculates were mouse-like or rat-like, but *Taeniolabis* (about one-third life-size) was almost as husky as a beaver. This group gave way to true rodents

2 There were no exclusively meat-eating animals, but the creodonts were the nearest approach, of which *Loxolophus* was typical. (About half life-size)

3 The condylarths were herbivorous counterparts of the creodonts. *Ectoconus,* shown here at about one-third natural size, is fully restored opposite

4 Least promising were the taeniodonts, represented by *Wortmania* (about one-third natural size). Their descendants became specialized, then died out

the red clay marks the end of one chapter and the beginning of another. We can put our fingers on the exact spot. Mark it well, because it is the visible record of the most dramatic event that ever occurred in the history of the world. Remote as it may seem to us, that was also the most important single event that ever occurred in our own history. If it had not happened, you and I, or anything human, would never have existed.

These upper, later clays look much the same as some far below. In what way do they represent a radical change in life history? Let us search them for organic remains. The most diligent scrutiny reveals no more of the great dinosaur bones. These are all gone, left one or two million years behind us, down the arroyo. But as we adjust our search to a different scale of magnitude we begin to find much smaller bones and tiny, many-cusped teeth, wholly unlike the dagger-like or serried teeth of the dinosaurs.

The hordes of bulky, cold-blooded dinosaurs are gone, vanished as if they had never been, and in their place are other hordes, even more numerous and varied but relatively insignificant in size and apparently feeble in comparison with the least of the lordly dinosaurs. The Age of Reptiles (the Mesozoic) has ended and the Age of Mammals (the Cenozoic) has begun.

The change here appears so sudden that it seems to give evidence for the old belief that the great reptiles, Rulers of the Mesozoic, were wiped out by catastrophic divine wrath and that the earth was repopulated by the creation of a gentler breed. But we now know that evolution, by and large, is a slow process and that when its results burst upon us with seeming rapidity they must be the culmination of long ages of preparation. So it is here. These herds of mammals that so quickly replaced the dinosaurs were not the first mammals to exist but were merely the first to become abundant and widespread.

Since almost the beginning of the Age of Reptiles mammals had existed. They had been small—a mammal larger than a rat was then a giant—and they had been obscure. Probably they were confined to limited areas and to peculiar environments where the competition with the omnipresent reptiles was not too lethal. The result is that they are among the rarest of fossils. Only here and there under exceptional conditions have their remains been found: in a limestone fissure in England, in a single quarry in Wyoming, and in wind-blown sands in the middle of the Gobi Desert. These and a few other discoveries show that mammals did persist during the dark ages of reptilian

dominance and that they were undergoing constant and fundamental evolutionary changes, oppressed by myriad foes, learning perforce to survive by some means other than reptilian brute strength.

The mammals may have contributed something to the downfall of the dinosaurs by eating the eggs of the latter, but they were far too feeble and too few to have been the sole or the most important factor in reptilian extinction at the end of the Age of Reptiles. As related in the December NATURAL HISTORY, the main reason for that extinction was probably that the dinosaurs finally became too sluggish and too inadaptive to meet the conditions of rapid changes in their environment.

The tiny, furry creatures that would have been the objects of scorn had dinosaurs been capable of that emotion, thus inherited the earth. They did so primarily because they were more adaptable. Their adaptability enabled them to survive the crisis of environmental change that slew the last of the giant reptiles. Once these reptiles were gone, this same adaptability enabled the mammals to multiply relatively rapidly and to adopt new modes of life, formerly closed to them by reptilian competition.

Definition of the word "mammal" means a great deal more than naming a few characteristics that enable us to recognize this kind of animal. We must also specify some of the things that enabled mammals to suceed in the struggle for existence and to take over the earth when the reptiles' long day was done. And out of this comes an explanation, partial at least, of why man himself was able to arise and to rule, for we are mammals, too, in one respect the mammals *par excellence*. The most basic mammalian character is intelligence. Small in size, without armor, without large fangs, the earliest mammals survived mainly because they used their heads. Unable to outfight dinosaurs, they outsmarted them. The essential upward trend in mammalian history is an increase in mental power, in grade of intelligence, culminating (up to now!) in man. There are, of course, relatively stupid mammals, and some of these, like the armadillo, have gone back to the old reptilian dodge of retreating into a shell; but the most stupid mammal is a mental prodigy in comparison with the most clever reptile.

The great majority of reptiles lay eggs, and all of them leave the young to fend for themselves from the start. The eggs may be spoiled by too cold a night or too hot a day, and eggs and young alike are peculiarly liable to attack by marauders against which their defenses are poor. With only two exceptions, mammals bring forth their young alive, reducing the hazards of the embryonic period to a minimum. Without exception, the young remain with the mother for some time and are nourished with her milk and protected by her against enemies. This not only enormously increases the young mammal's chances of survival but also gives it a relatively sheltered juvenile period in which it can adapt, learn, and acquire behavior patterns more complex than the almost entirely instinctive reactions of the young reptile. This opportunity to learn is related to the ability to learn—no mammalian characteristic is an isolated thing, but all are intimately correlated to produce a higher type of physical and mental functioning. The complex of growing intelligence and of juvenile care also involves the rudiments and the possibility of peculiarly mammalian sorts of conscious social structures, which again culminate in human society.

The more strictly physical structures and functions of mammals also differ profoundly from those of the ancestral reptiles. Mammals early acquired a complicated physiological mechanism for maintaining nearly constant body temperature. Thus they can survive and remain active in weather so cold that reptiles become dormant and finally freeze to death or in weather so hot that reptiles die of a sort of sunstroke. There is almost no climate so rigorous that mammals cannot somehow become adapted to it—this is probably the major secret that enabled the mammals to survive the great dying time of the reptiles at the end of the Mesozoic. Greater mammalian activity is also forwarded by improved bony and muscular structure. A mammalian thighbone, for instance, is more finished and more specifically adapted to special functions than is the corresponding bone of a reptile. A skilled mechanic at once recognizes the mammalian bone as being a better job. The mammal is capable of faster, more continuous action.

All these things—suckling the young, maintenance of body temperature, sustained activity—require a more rapid and constant utilization of energy within the mammal's body. This higher metabolism also implies a more steady food supply and a more efficient use of it. The whole body is involved in these activities, but we see them reflected most clearly, especially when dealing with fossils which preserve only the hard parts of animals, in the changing structure of jaws and teeth. The complicated reptilian jaws are made of many different bones, mechanically complex but so put together as to permit only a limited repertory of motions. In mammals the lower jaw is a single bone, strong and simple, with very wide possibilities of movement. Dinosaurs could not chew; they could only rend and chop with their teeth. In conjunction with their new jaw structure, mammals early acquired a peculiarly potent pattern of cuspidate, or pointed, teeth. This pattern was amazingly adaptable. Emphasis on one element or another in the process of evolution could produce specialized jaws equipped to take care of the most extreme varieties of food, each with maximum efficiency. Thus the mammals could find plenty where many of the reptiles would starve to death.

Those are some of the reasons why the humble, furry, little mammals were able to inherit the earth when their great chance came—when the going became too hard for the stronger, more abundant, but clumsier, less efficient, and less adaptable reptiles. Of the dozens of different kinds of reptiles in the Mesozoic very few survived into the mammalian age of the Cenozoic. None of the biggest reptiles could make the transition. Those that did survive — lizards, snakes, turtles and crocodiles—had the fortune to be adapted to environments that changed less radically and to ways of life in which they were less at a disadvantage in comparison with mammals.

Let us return to New Mexico and see what life was like there at the beginning of the Age of Mammals. The climate was certainly more moist than it is now and perhaps more equable. Broad rivers mean-

dered over the fertile plain that is now a desert, and groves of lush trees and shrubs abounded where scraggly sagebrush now grows.

Among the swarms of mammals, there is only one that is at all familiar to our eyes: a little opossum; for the opossum is the great conservative among mammals, an almost unmodified survival from the Age of Reptiles. The time is so remote that all the other animals have since either become extinct or have evolved into something unrecognizably different. It is difficult to describe these early mammals by any names derived from the recent fauna. It cannot be said that such and such an animal was an ancestral horse, because that ancestry was not yet sufficiently horse-like to be distinguishable, or that another animal resembled a cat, because the special cat-like habits and structures had not yet been differentiated. There is really no alternative to coining distinctive names for the ancient groups of mammals, and in this archaic New Mexican landscape most of the mammals we see are multituberculates, creodonts, condylarths, and taeniodonts.

Most of the little multituberculates were mouse-like or rat-like, although at this particular time some of them had achieved considerable size and were as large as husky beavers. They had enlarged, more or less rodent-like incisor teeth, and their cheek teeth were grinders covered with rows of tubercles—hence the name "multituberculate." The smaller kinds had also a set of large, sharp, scissor-like teeth in the middle of the jaw, for slicing off the skin and rind of fruits and vegetables. In that world the multituberculates played the part the ubiquitous rodents do in ours, but they were not true rodents. They were then the oldest type of mammal, a survival from the still dimmer past of the early part of the Age of Reptiles. Somewhere, as yet undiscovered, true rodents were probably even then beginning to evolve in obscurity. When their typical structure was well developed, they spread rapidly over the world. When this happened the multituberculates quickly became extinct without issue, for the habits were similar and the rodents were more efficient in the ensuing competition.

The carnivores and herbivores of today differ from each other so much that the thought of mistaking one for the other is ridiculous. Who could think that the fierce, flesh-eating tiger might be blood brother to the placid, grass-consuming cow? But in this ancient New Mexican fauna this specialization and differentiation of habits was barely beginning. The carnivores of the time — called creodonts — were less carnivorous, and the herbivores—condylarths—less herbivorous. There were no exclusively meat-eating animals like the tiger and no grazing animals like the cow. (In fact there were no grassy meadows to graze on; the meadows came later and with them, with typically mammalian adaptability, evolved grazing from more primitive browsing animals.)

Thus the creodonts and condylarths all looked very much alike, differing only in size and proportions and in minor anatomical details clear only on careful study. They were almost all rather squat, heavy-limbed animals with five toes, each ending in what was neither exactly a sharp claw nor a blunt hoof but something between the two. Their heads had more or less the simple proportions of the head of a dog or a bear, although not as pointed; but the braincase was smaller because the brain itself was still very primitive in comparison with the brain of later mammals. Their tails were long and clumsy, slowly tapering from an unusually heavy base. These animals varied from about the size of a rat to that of a police dog—there were no really large mammals as yet. Many of the smaller forms lived mostly in the trees, while the larger ones ambled about in the forests and glades.

A few of the creodonts were already specialized to the degree that they preferred a diet of carrion and only resorted to other food under the sharp stimulus of hunger; but most of these animals, creodonts and condylarths alike, were more or less omnivorous. Probably all of them ate some carrion when they found it. The more active creodonts may occasionally have been able to kill a multituberculate or an unwary condylarth. They all doubtless relished berries, fruits, and nuts. Some of the larger condylarths probably also relied heavily on succulent leaves and shoots in their diets.

Primitive as they were, these relatively clumsy mammals were full of promise for the future. The creodonts exemplified a type of structure that was capable of progressive adaptation into all the diverse sorts of later carnivores, and the condylarths foreshadowed the even greater diversity of later herbivores.

The other conspicuous members of the fauna, the taeniodonts, held no such promise. They were already beginning to specialize in a peculiar way that did, indeed, continue and intensify for some millions of years—but eventually it proved fruitless when the stock died out without further descendants. They exemplify a sort of unsuccessful experiment in adaptation, an early, aberrant line of specialization. The smaller, more primitive taeniodonts differed little from the creodonts, but the more peculiar large forms, with nearly the size but not the form of a collie, were still more strange. They had snub noses, heavy, deep jowls, strong, gnawing canine teeth, and large, blunt cheek teeth. Their bodies were peculiarly heavy and clumsy and their strong limbs, terminating in large claws, seem to have been adapted to digging and tearing up roots.

More progressive animals do not appear in this first, archaic fauna of the Age of Mammals as revealed by the famous fossil field of New Mexico's San Juan Basin. But somewhere, still isolated and hidden, they were already beginning to arise. As the millennia passed, from time to time some of these burst the bounds of environmental and geographical isolation and spread over much of the world. Thus in a few million years the modern true carnivores were to spread and, after a long struggle, to oust the survivors of their ancestral group, the creodonts. The early four-toed horses and other ungulates were similarly destined to replace the condylarths. Most significant of all, and sooner than the incursion of more advanced carnivores and ungulates, was to be the appearance of the primates, tiny lemurs and tarsiers, first forerunners of the long line leading to Man.

Be sure to read the next installment of the story of animal life in Natural History *for March.*

Painting by Francis Lee Jaques

Sixth installment in the story of animal life

Both North America and Europe became the scene of conflict some forty or fifty million years ago when a host of new animals swarmed in, possibly from Asia, menacing all those who could not defend themselves

NO MONKEYS appeared in the vanguard of the invasion, but their ancestors the lemurs were plentiful. A typical representative about forty million years ago was Notharctus, at left. Monkey-like hands, feet, and tail are characteristic of the lemurs, but the face is more fox-like. Lemurs did not survive in North or South America, but they are fairly abundant elsewhere today

No newspapers carried the headlines:

AMERICA INVADED

SHOCK TROOPS SWEEP FORWARD

INFILTRATION TACTICS THREATEN DEFENDERS

AMERICANS FALL BACK WITH STUBBORN RESISTANCE

THERE were no reporters to cover this great invasion. No human eye saw it, for it occurred long before man had appeared on the earth, tens of millions of years ago: some say 40 million and some say 50 million. Yet it had a greater effect on history—yes, on human history as well as on earth history—than any of the military campaigns of the mere six thousand years or so of what we are pleased to call history.

It was not the first invasion of America and it was not to be the last, but it was in many respects the most fateful. Already incredibly old, the earth had seen many races come and go. Perhaps a billion years before this, the first protoplasmic life had moved in the dark waters. Slowly, gropingly, as aeons passed, cells had clustered together, had formed muscles, skin, nerves, and glands. Fishes appeared, equipped with a wonderful new structure, bone, that gave them internal support, solving the problem of increased size and of greater speed, providing rigid support and yet giving freedom of directed motion. Crawling out of fetid pools, gasping for oxygen, the amphibians had finally learned to breathe air during their adult life; and some of their descendants, the reptiles, had completely broken the long bondage to water, for even their eggs could be laid on land and could survive without the watery bath required by all the earlier forms.

Then had come a great time. Surely an observer, had there then been one capable of rational thought, would have decided that the goal of evolution was reached. Through the air flapped and soared ugly, bat-like pterosaurs. Swift as torpedoes, streamlined ichthyosaurs sped through the waters, while marine dragons, the mosasaurs, sported with them, and the clumsier plesiosaurs sculled more placidly along. Above all, on land the motley hosts of dinosaurs held sway. Yet all these saurians were but an incident in history, even though a long incident of perhaps 140 million years, and they vanished mysteriously and were as forgotten as if they had never existed, until their remains were dug up by curious men.

That long time when the dinosaurs and all the other -saurs lived and dominated life is called the Mesozoic. The name means "middle life," and appropriately refers to the Medieval Era, the Dark Age, of earth history. When the saurians died and the meek mammals replaced them as previously described in this leaflet, the Cenozoic began, the "recent life" era. This was the beginning of modern history in the grand history of life, in which ten million years is like a century of human history. When students delving in the rocks first obtained some grasp of this sequence they found what seemed to be a fairly simple picture despite the multiplicity of its details. The dinosaurs were gone. Very well, that ended the Mesozoic. Mammals became abundant and no doubt they simply evolved into living faunas. So the period of that evolution can be called the Cenozoic, and for its first part no more appropriate

The Great Animal Invasion

By GEORGE GAYLORD SIMPSON [illegible] *The American Museum of Nat[illegible]*

name could be used than Eocene, which means "the dawn of the recent."

Now it is a troublesome fact that the more we know, the more we find to be known; the more we understand, the more appears that we do not understand. If they are acquiring some measure of wisdom and not merely being educated, students are likely to discover this distressing fact about the time they get into high school. Scientists, who are professional students and are paid for trying to find out a few of the multitude of things that ignorant man does not know, live all their lives with the discouraging conviction that their most distant journeys into the unknown are not much more extensive, relatively, than if they were ants setting out to explore North America.

All this is by way of introducing the news that paleontologists had hardly named the Eocene and started the interesting task of tracing the descent of animals from that time to this, when they began to find facts that did not fit into the picture. They found that the Eocene did not immediately follow the extinction of the great reptiles at the end of the Mesozoic, but that some time intervened. The longer they studied, the longer this interval appeared to be, until now it is believed to have lasted for at least ten million years, possibly fifteen million. Rocks deposited in that interval are not very widespread; but now almost a complete sequence of them has been found in our Rocky Mountain states, and some strata representing more limited parts of the interval have also been found in Europe, Asia, and South America. Fossils occur in these rocks and they show that mammals were the dominant, common animals of the time.

So far, so good. This unexpected interval belongs to the Age of Mammals and fits into the Cenozoic. The name Eocene had already been given to a later epoch before it was found that this was not really the beginning of the Cenozoic, so a new name had to be coined for the true beginning and it has been called Paleocene, which means "ancient-recent." It is a rather absurd appellation if taken literally, but paleontologists agree to use it, and it serves all the purposes of a name and is less confusing than if the

NO ONE KNOWS just where the invading animals came from. South America, then separated from North America, avoided the invasion until several million years later

Drawing by John C. Germann

THE GROTESQUE ARCHAIC uintatheres *(center)* were doomed to extinction when faced by progressive invaders like the ancestral horses *(right)*

use of the more appropriate "Eocene" had been changed.

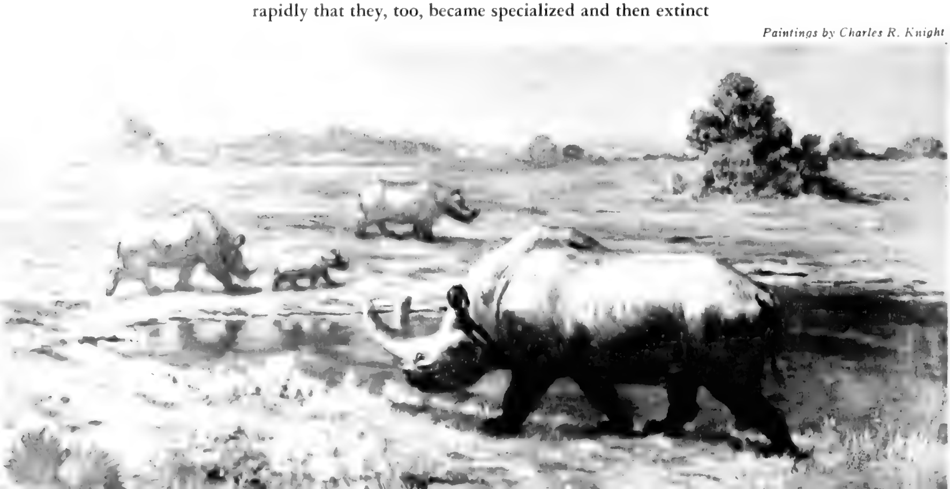
The trouble was that the mammals of this unexpected extra epoch, the Paleocene, do not simply grade into the ancestry of modern mammals. Something very queer, and at first sight inexplicable, happened at about the beginning of the Eocene. Take the ancestry of the horse, for instance. Everyone knows that this can be traced back almost continuously to little Eohippus, a small animal with four front and three hind toes that lived in Europe and North America at the beginning of the Eocene, the "dawn-horse" in the "dawn of the recent." But where did Eohippus come from? Since the long Paleocene, with its varied mammals, preceded the Eocene, obviously it is the place to look for the ancestor of Eohippus.

There are, indeed, animals in the Paleocene that could have given rise to Eohippus. These are the condylarths, the first hoofed, herbivorous mammals, described in the first part of this leaflet. The problem seemed to be solved, but paleontologists continued to pry and they learned so much that they found that they knew less than they had thought. They found that the condylarths evolved slowly and steadily through the Paleocene but that when Eohippus appeared the condylarths were still here and were still much more primitive than Eohippus and quite different. Apparently these condylarths, at least those known in North America, did not evolve into Eohippus. The same sort of difficulty appeared not only for the horses, but also for all the modern types of herbivores, the pigs, cows, antelopes, and the rest, and for the rodents and for many other recent types of mammals.

Here are the makings of a game more exciting than "Murder" and more difficult than crossword puzzles. The reader can try it, if he likes, as a superior sort of guessing game. The question is: *Why does the first animal we can class as a horse differ so much from its only possible known ancestors?* The scientific method of attack on the problem does, indeed, follow some of the lines of a guessing game. A first step is to think of all conceivably possible explanations. In scientific research these are called "multiple hypotheses." You might try this yourself before reading the multiple hypotheses that scientists have set up for this particular problem. The most important of these hypotheses are:

SOME OF THE INVADERS, like the great titanotheres *(below)* progressed so rapidly that they, too, became specialized and then extinct

Paintings by Charles R. Knight



FIVE HYPOTHESES are considered in explanation of why horse ancestors appeared suddenly in North America. They are:

1 that Eohippus, the Dawn Horse, was created by divine act

2 that the geologic record in North America was interrupted during the time when Eohippus was evolving

3 that certain animals unlike Eohippus but related to him, suddenly gave birth to a litter of Dawn Horses

4 that fossil hunters in North America have as yet merely failed to find the connecting links in horse ancestry, and

5 that the Dawn Horse was evolved elsewhere than in North America and arrived on this continent along with other invading animals

1. Eohippus was created by divine power and did not evolve from any earlier form. This was accepted by scientists a hundred years ago and is still claimed by a few theologians, but it cannot now be seriously considered by any thoughtful inquirer. This is no place to go over the threadbare arguments, but if you feel like arguing, mull over just one fact: the whole sequence from Eohippus to modern horse is very well known and shows beyond question that the latter is derived from the former; but some condylarths are much more like Eohippus than Eohippus is like the modern horse.

2. Eohippus did arise from condylarths in a (hypothetical) long interval between Paleocene and Eocene when no known rocks, and hence no known fossils, were deposited. This is a plausible hypothesis, but, as it happens, one that can now be disproved beyond any doubt. One of several conclusive lines of disproof is this: condylarths are known both in the late Paleocene and in the early Eocene contemporaneous with Eohippus; they are very much alike in the two epochs; if they changed so little, no length of time sufficient for the slow origin of Eohippus can have intervened.

At which point you may interrupt me to say, "How about the scare headlines with which you began this article. Was that just a come-on to get me to plow through all this stuff?"

"Not at all," I would answer. "This 'stuff' as you call it, has a very direct bearing on those headlines. We'll be back to the invasion sooner than you expect."

3. Eohippus did arise from the condylarths, but did so all at once and not slowly. Perhaps condylarth mates suddenly had a litter of Eohippuses at the beginning of the Eocene. In the nature of things, this hypothesis cannot be ruled out categorically and some respectable scientists (as it happens, not those best acquainted with the facts of mammalian history) do support it. Nevertheless it is so improbable as to be unacceptable unless we can find no hypothesis more likely to explain the observed facts. No such radical jump ever occurred in the later evolution of the horse, or in any other group represented by a good fossil record, so what logical right have we to assume that it happened here unless there is no other explanation?

4. Some line of American condylarths, evolving more rapidly than those known, did give rise to Eohippus during the Paleocene but simply has not been discovered. Again, the hypothesis cannot be disproved—who can say what may yet be discovered? It was even a likely hypothesis before much was known about the American Paleocene, but as hundreds and thousands of Paleocene fossils are found, many of them clearly from environments suitable for Eohippus, and not a scrap of a real Eohippus ancestor appears, the chance that such ancestors occurred here is being reduced to the vanishing point.

5. Eohippus evolved from condylarths some place else and it appears suddenly at the beginning of the American Eocene because something—perhaps the rise of land joining various continents—then permitted the herds of Eohippuses and other typical Eocene mammals to invade North America.

This is the favored hypothesis of paleontologists. It explains all the known facts, no fact contradicts it, and it is supported by other observations and theories on all sides. Thus it becomes something more than a hypothesis (which is a scientific guess set up for examination and testing) and becomes a full-fledged theory (the most probable, best supported explanation of a body of observations). The next step —from theory to an attested fact—would be the finding of the ancestry and the tracing of the actual steps of the invasion radiating from a center. Such a discovery has not been made. Perhaps it never will be. It is quite possible that the center of origin is now sunk beneath the sea or that no fossils survive in it. But in any case the theory is established and seems almost certainly to be true.

Ancestors from abroad

With a few exceptions, the known American Paleocene mammals were archaic types. They were related to the ancestry of later mammals and give us some idea of what those ancestors were like, but they were not themselves the real, direct ancestors. Life today would be very different if the Paleocene mammals had continued to occupy the earth and to evolve into the only living types. Hardly a single mammal that we know today would have existed. The ancestors came in during the Great Invasion.

This did not happen all at once. Some groups invaded earlier, some later, but the climax of the change came at about the beginning of the Eocene, so that the name of the "dawn of the recent" epoch is still appropriate. The archaic Paleocene groups did not die out all at once, either. Most of them were certainly doomed, because they were less efficient or less intelligent than various modernized mammals of similar habits and could not win in the long competition. Nevertheless many of the archaic mammals hung on, some of them for millions of years, and continued to evolve in their own ways before they finally succumbed.

Let us briefly review a typical mammalian fauna of, say, the middle Eocene when the invaders were well established but some of the ancient inhabitants were still holding out. A good example is the fossil fauna of the Bridger Basin of southwestern Wyoming. In the middle Eocene much of this region, now barren, was heavily forested. The animals roamed through the forests, glades, and smaller savannahs of a broad valley. Distant volcanoes thundered; falls of volcanic ash were frequent, but seldom so dense as to cause wide slaughter. To the south was a lake basin already almost filled by millenniums of ash falls and by the sediments of rivers but still with shallow open water in the middle Eocene.

To the instructed eye, perhaps the most striking animals of the time were some of the smallest, the rodents. The rodent-like multituberculates of the Mesozoic and Paleocene were among the first of the archaic mammals to fall before the invaders. Now,

in the Eocene, they are all gone and in their places are multitudes of true rodents. Numerous as these are, they are not nearly as varied as are the recent rodents of Wyoming. They are still primitive, just beginning to specialize in various directions, and all are more or less squirrel-like,—for squirrels, despite a few specializations, are about the most primitive of rodents surviving today and therefore most like these ancestral forms.

Passing giants

The largest and most impressive animals are the uintatheres, almost as large as elephants and elephant-like in their bodies but with very different heads, elongate and provided with three pairs of blunt, horn-like protuberances. Although they are herbivores, they have great saber-like canine teeth and use these to fight, not to kill prey. The fate of the dinosaurs is sufficient warning that size is not adequate insurance of survival. Indeed, these grotesque uintatheres are stupid survivors of the archaic fauna and they are to die out by the end of the Eocene.

Other archaic herbivorous survivors are condylarths, so varied in the Paleocene but now reduced to one kind which is, nevertheless, abundant, and taeniodonts, strange misfits that we saw at the beginning of the Paleocene. Both these groups, like the uintatheres, are destined not to survive the Eocene.

But there are others,—more varied and more numerous herbivores of modernized groups, Eocene invaders prophetic of the future. Among these are ancestral horses, Orohippus, differing little from its immediate ancestor Eohippus. Rhinoceroses are particularly common and there are many different sorts. Ancestral tapirs also occur. There are many titanotheres, odd-toed allies of horses and rhinoceroses and therefore modernized or progressive. They evolved more rapidly to a maximum and became extinct in the next epoch, the Oligocene. Even among the modernized groups that invaded in the Eocene there were many aberrant side lines that do not survive today.

The even-toed hoofed mammals, later dominant among all herbivores, are present in this middle Eocene fauna but are still rare. As yet only a few occur, rather small and too primitive to describe in terms of recent animals. Later their evolution seems to have speeded up and they passed the odd-toed forms, giving rise to such diverse creatures as pigs, hippopotamuses, camels, deer, antelopes, sheep, cows, and many others.

Flesh-eaters largely archaic

What of the flesh-eaters that preyed on all these herbivores? Here it is curious to note that the archaic types are still dominant. Varied creodonts, much like those of the Paleocene but in some cases swifter or more powerful, have developed from Paleocene ancestors without being replaced by invading modernized types. Some, indeed, are relatively advanced but the most potent invaders, of the cat, dog, and weasel families, had not yet made their way into North America. When they did, in the next epoch, the creodonts did not long survive the competition.

Perhaps the greatest popular interest is attracted by the presence of numerous primates, for this group of mammals includes the monkeys, apes, and man. None of these higher types, not even one as high as a monkey, has yet appeared in the middle Eocene; but lower primates are common, especially primitive lemurs. The lemurs, some of which still survive in the warmer parts of the Old World, have monkey-like hands, feet, and tails, but most of them have long, fox-like faces instead of the short, flattened faces so typical of monkeys—and of man, for that matter. (Our naked, smashed-in snouts perhaps look quite disgusting to a lemur.) The primate invasion started well back in the Paleocene, but the commonest middle Eocene type, a fairly typical primitive lemur called Notharctus, is of a more modern stock that invaded with Eohippus at the beginning of the Eocene. For some reason primates did not do very well in North America, where only a few survived the Eocene and none the next epoch, the Oligocene. That they survived abundantly elsewhere in the world is history.

The Great Invasion occurred almost simultaneously in Europe and North America and, as already mentioned, its source is not clear, although a number of students think that the main source, at least, was somewhere in Asia. Now it has been found that essentially the same invasion occurred in South America at a very much later date and under circumstances that permit its being followed from start to finish in considerable detail. This clear example helps to support the theory of an Eocene invasion in North America and, by analogy, to fill in some of the interpretive gaps left by incomplete factual knowledge of that earlier event.

This is what happened: the great Mesozoic dinosaurs and other -saurs also disappeared in South America at the Great Dying Time, and the Cenozoic started there, as in North America, with the appearance of the varied archaic mammals of the Paleocene. Then South America was isolated by the sea and it became an island continent. The modernized Eocene invaders of North America could not reach South America, and while the archaic fauna was fighting a losing struggle in the north, it had no competition (outside its own ranks) in the south and continued to flourish there. It evolved, too, of course, but the South American fauna was essentially archaic almost to the end of the Pliocene—a mere one or two million years ago—which was long after the great majority of archaic mammals had died out in the north.

Then the Isthmus of Panama rose. The modernized mammals of North America, evolved now into such familiar forms as foxes, raccoons, bears, wild cats, peccaries, deer, horses, and tapirs, invaded South America over this land route. In the ensuing bitter struggle a few of the archaic forms, like the armadillos, managed to survive and even to get a foothold in North America, but almost all of them became extinct and were replaced by the modernized mammals of northern origin. It was the Eocene struggle over again, long delayed by the accident that South America was an island in the Eocene and for long after.

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